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DEPROP - A DIGITAL COMPUTER PROGRAM FOR PREDICTING DYNAMIC ELASTIC-PLASTIC RESPONSE OF PANELS TO BLAST LOADINGS

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The DEPROP digital computer program determines the dynamic elastic-plastic, large displacement response of cylindrical and flat panels to arbitrary blast loadings. The program computes strain, stress, displacement and boundary reaction force time histories for linear elastic and elastic-plastic solution options. The theoretical formulation and program description of DEPROP are presented in the form of a User's Manual.

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PREFACE

This work was performed by the Structural Mechanics Group of Kaman AviDyne, 83 Second Avenue, Northwest Industrial Park, Burlington, Massachusetts 01803 with the Air Force Armament Laboratory, Armament Development and Test Center, Eglin Air Force Base, Florida. Mr. William S. Strickland (DLYV) was technical monitor for the Air Force Armament Laboratory, and Mr. Lawrence J. Mente was project leader for Kaman AviDyne. Mr. E. S. Criscione is Head of the Structural Mechanics Group of Kaman AviDyne. This effort was conducted during the period from 14 January 1976 to 29 June 1976.

The authors wish to thank Mr. William S. Strickland of the Air Force Armament Laboratory for the formulation of the pressure model on a panel subjected to a projectile explosion in an adjacent fluid medium. This pressure model appears as loading option 1 in the program.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER:

J R Murray

J. R. MURRAY
Chief, Weapon Systems Analysis Division

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INTRODUCTION

One aspect of aircraft vulnerability to blast loadings involves the capability to predict the dynamic response of aircraft panels in the severe permanent damage range. The structural response program DEPROP was developed in Reference 1 to calculate the linear elastic and elastic-plastic, large displacement dynamic response of cylindrical or flat panels to the pressure loading associated with a nuclear blast wave intercepting an aircraft in flight. In this program the loading was assumed to be uniform over the panel and, therefore, only symmetrical response modes were used in the solution. The purpose of this study is to develop a User's Manual for DEPROP which is applicable to general non-nuclear blast loadings. This version of DEPROP computes strain, stress, displacement and reaction boundary force responses to an arbitrary transient pressure loading which could excite both symmetrical and anti-symmetrical response modes. This geometric and physical non-linear dynamic response program provides any combination of clamped and simply supported boundary conditions for cylindrical and flat panels which are single or multi-layered with isotropic or orthotropic material properties. The DEPROP program's elastic option can be used with multiple layers of isotropic or orthotropic material while the inelastic option is restricted to use with only single layer isotropic panels based on an assumed bilinear stress-strain material representation. The DEPROP analysis is based on the Novozhilov nonlinear strain-displacement relations for large displacement response of thin panels using the assumption of undeformable normals. The inelastic formulation is based on the Mises-Hencky yield surface, a kinematic hardening model and the Hencky stress-strain relations from the deformation theory of plasticity with modifications for regions of elastic unloading and reyielding.

This User's Manual for the DEPROP program presents the theory and program description necessary to facilitate the use of the program.

Section II presents the basic formulation of the nonlinear panel response analysis. The program description and operation are given in Section III which contains a brief description of each routine and associated flow diagrams, definition of program variables, program input data description and program output description. The program listing is presented in Appendix B.

SECTION II

PANEL RESPONSE ANALYSIS

The basic analytical formulation for DEPROP is given in Reference 1 and is repeated herein for completeness of the presentation and better understanding of the DEPROP program. The modifications and extensions of DEPROP involving the anti-symmetrical response modes, boundary reaction forces, and arbitrary loading representation have been included in the presentation of the analytical formulation.

2.1 Basic Theory

The single-layered cylindrical panel is considered to have a constant thickness h, mean radius a, subtended angle θ_o and length ℓ. The cylindrical coordinates (x, θ, z) and the axial, tangential, and radial displacement components (u, v, w) are shown in Figure 1 on the coordinate surface which is located at the median surface of the panel. The governing equations of motion for the panel are obtained from the principle of virtual work for a dynamic structural system (Reference 2) which is given by

$$\int_{t_1}^{t_2} \left[\iiint_V \sigma_{ij}\, \delta\tilde{\varepsilon}_{ij}\, dV - \delta T - \iint_A \bar{F} \cdot \delta\bar{d}\, dA \right] dt = 0 \qquad (1)$$

where the panel is undergoing an arbitrary set of infinitesimal virtual displacements δu, δv, δw that satisfy the geometrical boundary conditions and vanish at $t=t_1$ and t_2; T is the kinetic energy; σ_{ij} are the components of total stress; $\tilde{\varepsilon}_{ij}$ are the components of total strain; $\bar{F}$ is the surface force vector; $\bar{d}$ is the displacement vector; and integrations are carried over volume V and deformed surface area A. It should be noted that this principle holds regardless of whether the material's stress-strain relations are elastic or inelastic and whether the force system is conservative or nonconservative. If it is assumed that $T = T(\dot{u}, \dot{v}, \dot{w})$, then

$$\delta T = \frac{\partial T}{\partial \dot{u}}\, \delta\dot{u} + \frac{\partial T}{\partial \dot{v}}\, \delta\dot{v} + \frac{\partial T}{\partial \dot{w}}\, \delta\dot{w} \qquad (3)$$

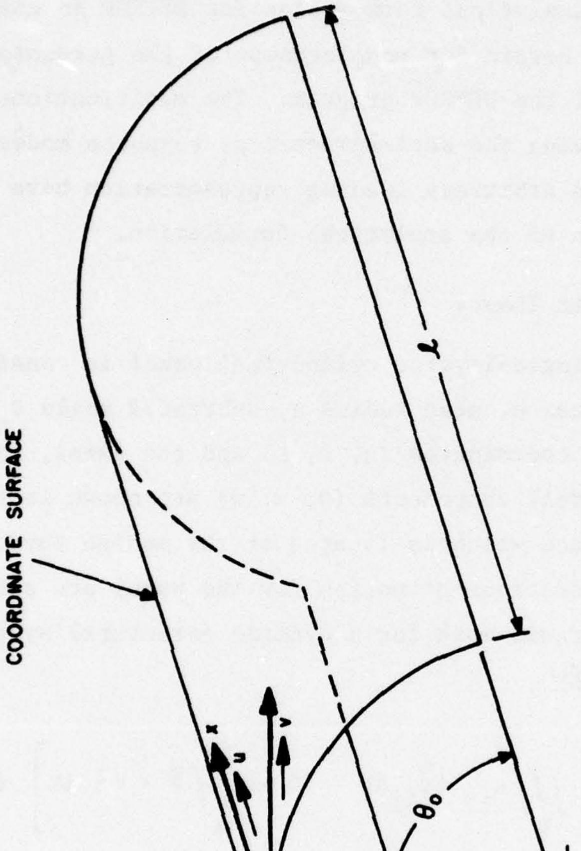


Figure 1. Coordinate Surface for Cylindrical Panel

where the dots denote differentiation with respect to time. With Equation (2) and using integration by parts,

$$\int_{t_1}^{t_2} \delta T \, dt = - \int_{t_1}^{t_2} \left(\frac{d}{dt} \frac{\partial T}{\partial \dot{u}} \delta u + \frac{d}{dt} \frac{\partial T}{\partial \dot{v}} \delta v + \frac{d}{dt} \frac{\partial T}{\partial \dot{w}} \delta w \right) dt \qquad (3)$$

It is assumed that the blast pressure, $p(x,\theta,t)$, acts on the coordinate surface of the cylindrical or flat panel. As the panel surface deforms, the elemental pressure force vector remains normal to the coordinate surface so that it changes direction during deformation. The magnitude of this force vector also changes as the element surface area of the deformed panel changes. It should be noted that the portion of the pressure loading associated with the force vector's dependence on the deformations represents a nonconservative force system. Based on the rectangular coordinate system (X,Y,Z), the components η_X, η_Y and η_Z of the inward unit normal surface vector and the components d_X, d_Y and d_Z of the displacement vector $\bar{d}$ were defined in Reference 2 in terms of u, v and w and their spatial derivatives. Thus, the vector dot product of the force and virtual displacement is expressed as

$$\bar{F} \cdot \delta\bar{d} = p(x,\theta,t)(\eta_X \delta d_X + \eta_Y \delta d_Y + \eta_Z \delta d_Z) \qquad (4)$$

By neglecting terms above the second order and recasting in terms of the virtual displacements δu, δv and δw, the virtual work done by the forces is given by

$$\iint_A \bar{F} \cdot \delta\bar{d} \, dA = \iint_{\bar{A}} p(x,\theta,t)(N_u \delta u + N_v \delta v + N_w \delta w) d\bar{A} \qquad (5)$$

where

$$N_u = -(w_x + \overset{\circ}{w}_x)$$

$$N_v = -(w_\theta + \overset{\circ}{w}_\theta + v)/a$$

$$N_w = 1 - (w + \overset{\circ}{w} - v_\theta)/a + u_x$$

$$\bar{A} = \text{undeformed surface area}$$

The subscripts on the displacement components denote spatial derivatives and $\overset{\circ}{w}$ denotes initial radial imperfection in the panel.

With Equations (3) and (5) and the relation

$$\delta\tilde{\varepsilon}_{ij} = \frac{\partial\tilde{\varepsilon}_{ij}}{\partial u}\,\delta u + \frac{\partial\tilde{\varepsilon}_{ij}}{\partial v}\,\delta v + \frac{\partial\tilde{\varepsilon}_{ij}}{\partial w}\,\delta w,$$

Equation (1) becomes

$$\int_{t_1}^{t_2}\Bigg\{\left[\frac{d}{dt}\,\frac{\partial T}{\partial \dot{u}} + \iiint_V \sigma_{ij}\,\frac{\partial\tilde{\varepsilon}_{ij}}{\partial u}\,dV - \iint_A pN_u\,d\bar{A}\right]\delta u + \left[\frac{d}{dt}\,\frac{\partial T}{\partial \dot{v}}\right.$$

$$\left. + \iiint_V \sigma_{ij}\,\frac{\partial\tilde{\varepsilon}_{ij}}{\partial v}\,dV - \iint_A pN_v\,d\bar{A}\right]\delta v + \left[\frac{d}{dt}\,\frac{\partial T}{\partial \dot{w}}\right.$$

$$\left. + \iiint_V \sigma_{ij}\,\frac{\partial\tilde{\varepsilon}_{ij}}{\partial w}\,dV - \iint_{\bar{A}} pN_w\,d\bar{A}\right]\delta w\Bigg\}\,dt = 0 \qquad (6)$$

The displacement components are assumed in the following truncated series form with undetermined time-dependent coefficients, $u_{mn}(t)$, $v_{mn}(t)$, $w_{mn}(t)$:

$$u(x,\theta,t) = \sum_{m=1}^{M} \sum_{n=1}^{N} u_{mn}\phi_m^u(x)\phi_n^u(\theta)$$

$$v(x,\theta,t) = \sum_{m=1}^{M} \sum_{n=1}^{N} v_{mn}\phi_m^v(x)\phi_n^v(\theta)$$

$$w(x,\theta,t) = \sum_{m=1}^{M} \sum_{n=1}^{N} w_{mn}\phi_m^w(x)\phi_n^w(\theta) \tag{7}$$

where $\phi_m(x)$ and $\phi_n(\theta)$ are functions that satisfy the geometric boundary conditions of the panels. The initial radial imperfection in the panel is represented by

$$\overset{\circ}{w}(x,\theta) = \sum_{m=1}^{M} \sum_{n=1}^{N} \Delta_{mn}\phi_m^w(x)\phi_n^w(\theta) \tag{8}$$

where Δ_{mn} are prescribed values based on known or assumed deviations from the ideal shape of the panel. Based on Equation (7), the following relations are obtained:

$$\delta u = \sum_{m=1}^{M} \sum_{n=1}^{N} \delta u_{mn}\phi_m^u\phi_n^u, \quad \delta v = \sum_{m=1}^{M} \sum_{n=1}^{N} \delta v_{mn}\phi_m^v\phi_n^v, \quad \delta w = \sum_{m=1}^{M} \sum_{n=1}^{N} \delta w_{mn}\phi_m^w\phi_n^w$$

$$\frac{\partial u}{\partial u_{mn}} = \phi_m^u\phi_n^u, \quad \frac{\partial v}{\partial v_{mn}} = \phi_m^v\phi_n^v, \quad \frac{\partial w}{\partial w_{mn}} = \phi_m^w\phi_n^w \tag{9}$$

Introducing Equation (9) into Equation (6) and since δu_{mn}, δv_{mn} and δw_{mn} are arbitrary, the following 3MN equations of motion are obtained:

$$\frac{d}{dt}\,\frac{\partial T}{\partial \dot{u}_{mn}} + \iiint_V \sigma_{ij}\,\frac{\partial \tilde{\varepsilon}_{ij}}{\partial u_{mn}}\,dV - \iint_A \tilde{Q}^u_{mn}\,d\bar{A} = 0 \tag{10a}$$

$$\frac{d}{dt}\,\frac{\partial T}{\partial \dot{v}_{mn}} + \iiint_V \sigma_{ij}\,\frac{\partial \tilde{\varepsilon}_{ij}}{\partial v_{mn}}\,dV - \iint_{\bar{A}} \tilde{Q}^v_{mn}\,d\bar{A} = 0 \tag{10b}$$

$$\frac{d}{dt}\,\frac{\partial T}{\partial \dot{w}_{mn}} + \iiint_V \sigma_{ij}\,\frac{\partial \tilde{\varepsilon}_{ij}}{\partial w_{mn}}\,dV - \iint_{\bar{A}} \tilde{Q}^w_{mn}\,d\bar{A} = 0 \tag{10c}$$

$(m=1,2,3\ldots M) \qquad (n=1,2,3\ldots N)$

where the integrands of the generalized forces ($\tilde{Q}^u_{mn}$, $\tilde{Q}^v_{mn}$, $\tilde{Q}^w_{mn}$) are given by

$$\tilde{Q}^u_{mn} = pN_u\,\frac{\partial u}{\partial u_{mn}}\,, \quad \tilde{Q}^v_{mn} = pN_v\,\frac{\partial v}{\partial v_{mn}}\,, \quad \tilde{Q}^w_{mn} = pN_w\,\frac{\partial w}{\partial w_{mn}} \tag{11}$$

The kinetic energy of a single-layered panel is given as

$$T = \frac{a\rho h}{2}\int_0^{\ell}\int_0^{\theta_o} (\dot{u}^2 + \dot{v}^2 + \dot{w}^2)\,dx\,d\theta \tag{12}$$

where ρ is the mass density of the material and the dots denote differentiation with respect to time. The rotary inertia contributions to the kinetic energy have been neglected. Modification of the mass density for multilayered panels is introduced in subsection 2.5. Further development of Equation (10) depends upon the establishment of the strain-displacement relations, the stress-strain relations, and the displacement component spatial functions.

2.2 Strain-Displacement Relations

The strain-displacement relations used in this analysis are based on the assumptions: (1) strains are small compared with unity, (2) the thickness of the shell is small compared with the radius and (3) the Kirchhoff - Love hypothesis that straight fibers which are normal to the undeformed coordinate surface remain straight and normal to the deformed coordinate surface and are not elongated, thus neglecting transverse shear and normal strains. The basic formulation of the following set of nonlinear strain-displacement relations is attributed to Novozhilov (Reference 4). The total strain consists of membrane and bending components expressed by the form $\tilde{\varepsilon} = \varepsilon + z\kappa$. The membrane elongation and shear strains (ε_{xx}, $\varepsilon_{\theta\theta}$, $\varepsilon_{x\theta}$) on the coordinate surface are expressed in terms of the displacement components and their spatial derivatives:

$$\varepsilon_{xx} = u_x + \frac{1}{2}\left[w_x^2 + u_x^2 + v_x^2\right] + w_x \overset{\circ}{w}_x \tag{13a}$$

$$\begin{aligned}\varepsilon_{\theta\theta} &= \frac{1}{a} v_\theta - \frac{1}{a}\lambda w + \frac{1}{2a^2}\left[(w_\theta + \lambda v)^2\right. \\ &\quad \left. + (v_\theta - \lambda w)^2 + u_\theta{}^2\right] + \frac{1}{a^2} w_\theta \overset{\circ}{w}_\theta\end{aligned} \tag{13b}$$

$$\begin{aligned}\varepsilon_{x\theta} &= v_x + \frac{1}{a} u_\theta + \frac{1}{a} w_x (w_\theta + \lambda v) + \frac{1}{a} v_x (v_\theta - \lambda w) \\ &\quad + \frac{1}{a} u_\theta u_x + \frac{1}{a}(\overset{\circ}{w}_x w_\theta + \overset{\circ}{w}_\theta w_x)\end{aligned} \tag{13c}$$

Similarly, the change of curvature quantities (κ_{xx}, $\kappa_{\theta\theta}$, $\kappa_{x\theta}$) of the coordinate surface which characterize the bending and torsional deformations of the panel are given by

$$\kappa_{xx} = w_{xx}\,(1 + v_\theta/a - \lambda w/a + u_x) \qquad (14a)$$

$$\kappa_{\theta\theta} = \frac{1}{a^2}\,w_{\theta\theta} + \frac{\lambda}{a^2}\,v_\theta + \frac{\lambda}{a^2}\,(-w + v_\theta) + \frac{\lambda}{a}\,u_x$$

$$+ \frac{1}{a^3}\,(w_{\theta\theta} + \lambda v)(v_\theta - \lambda w) \qquad (14b)$$

$$+ \frac{1}{a^2}\,w_{\theta\theta}u_x + \frac{\lambda}{a^3}\,(v_\theta - w)^2 + \frac{\lambda}{a^3}\,(w_\theta + v)^2$$

$$+ \frac{\lambda}{a^3}\,w_\theta(w_\theta + v)$$

$$\kappa_{x\theta} = \frac{2}{a}\,w_{x\theta} + \frac{\lambda}{a}\,v_x + \frac{2}{a^2}\,w_{x\theta}\,(v_\theta + a u_x - \lambda w)$$

$$+ \frac{2\lambda}{a^2}\,w_x(w_\theta + v) \qquad (14c)$$

Primarily, only those nonlinear terms are included in Equation (14) which involve the radial displacement and its derivatives. The subscripts on the displacement components in Equations (13) and (14) denote partial spatial derivatives. The end terms in Equation (13) are included to account for the initial radial imperfection of the panel as indicated by Donnell's representation in Reference 5. The parameter λ is introduced in the strain-displacement relations so that they apply to both curved and flat panels. Thus, $\lambda = 1$ for curved panels. For flat panels, $\lambda = 0$, $a = 1$, θ is replaced by y, and θ_o is replaced by b, the width of the flat panel.

2.3 Constitutive Relations

In DEPROP, the behavior of the panel material is treated as elastic-plastic for isotropic single-layered panels and elastic for isotropic and orthotropic multilayered panels. The elastic-plastic analysis for the single-layered panel has been established as the basic formulation in the DEPROP program. The elastic multilayered analysis is established as an alternate option based on appropriate modifications of the elastic-plastic formulation. In the DEPROP analysis the solution involves total strains and stresses; therefore, for response in the inelastic region, it is convenient to use the deformation theory of plasticity instead of flow theory which involves incremental strains and stresses. Plastic deformation theory is based on an averaging process that permits a total strain solution dependent upon only the final stress state at the end of a loading path. In general, deformation theory is an approximation of the more rigorous flow (incremental) theory but is equivalent to flow theory for an elastic-plastic material when the stress loading is proportional, *that is, the ratio of principal* stresses remain constant during the loading process. However, since the dynamic response solution is solved incrementally in time by numerical methods in DEPROP, the strain increments are small and the stress state is fairly constant in the plastic region over each time step for which the equations of motion are solved. Thus, the plastic deformation theory provides a much more accurate solution when the averaging process takes place separately over each small time increment as the response solution is obtained by a step-by-step timewise procedure.

In deformation theory the total strain is a function of the state of stress and consists of a recoverable elastic component and a nonrecoverable plastic component. It is assumed that the material is incompressible, that is, no permanent change in volume, due to the plastic strain. Thus, the total plastic strain is equal to the deviator plastic strain. Furthermore, it is assumed that the material's uniaxial stress-strain curve is modeled by the bilinear representation shown in Figure 2 in which the strain hardening is defined by slope E_t. This stress-strain representation is interpreted for the biaxial state of stress through the use of the effective stress ($\bar{\sigma}$)-effective strain ($\bar{\varepsilon}$) concept, in which the secant modulus (E_s) indicated in Figure 2 is defined by

$$E_s = \frac{\bar{\sigma}}{\bar{\varepsilon}} = \frac{\sigma_o + E_t (\bar{\varepsilon} - \varepsilon_o)}{\bar{\varepsilon}} \tag{15}$$

where σ_o, ε_o are the yield stress and strain, respectively, from the material's uniaxial bilinear representation. Thus, the effective stress, effective strain, and secant modulus quantities are used to relate the biaxial stress-strain condition to the assumed uniaxial bilinear stress-strain representation for the isotropic material. The effective stress and strain, expressed as $\bar{\sigma} = f(\sigma_{ij})$ and $\bar{\varepsilon} = g(\tilde{\varepsilon}_{ij})$, are functions of the total stress and strain components, respectively, and are more conveniently introduced in explicit form later in the development.

The Hencky stress-strain relations for deformation theory (Reference 6) are used in the plastic region and are given in the following form:

$$\tilde{\varepsilon}_{ij} = \frac{1}{E} [(1+\nu)\sigma_{ij} - \nu\sigma_{kk}\delta_{ij}] + \frac{3}{2} (\frac{1}{E_s} - \frac{1}{E}) [\sigma_{ij} - \frac{1}{3} \sigma_{kk}\delta_{ij}] \tag{16}$$

where E is the modulus of elasticity, ν is Poisson's ratio and δ_{ij} is the Kronecker delta. The first portion of Equation 16 represents the elastic component of strain while the second portion represents the plastic component of strain in terms of the deviator stress. For use in Equation (10), the stress-strain relations in Equation (16) are inverted

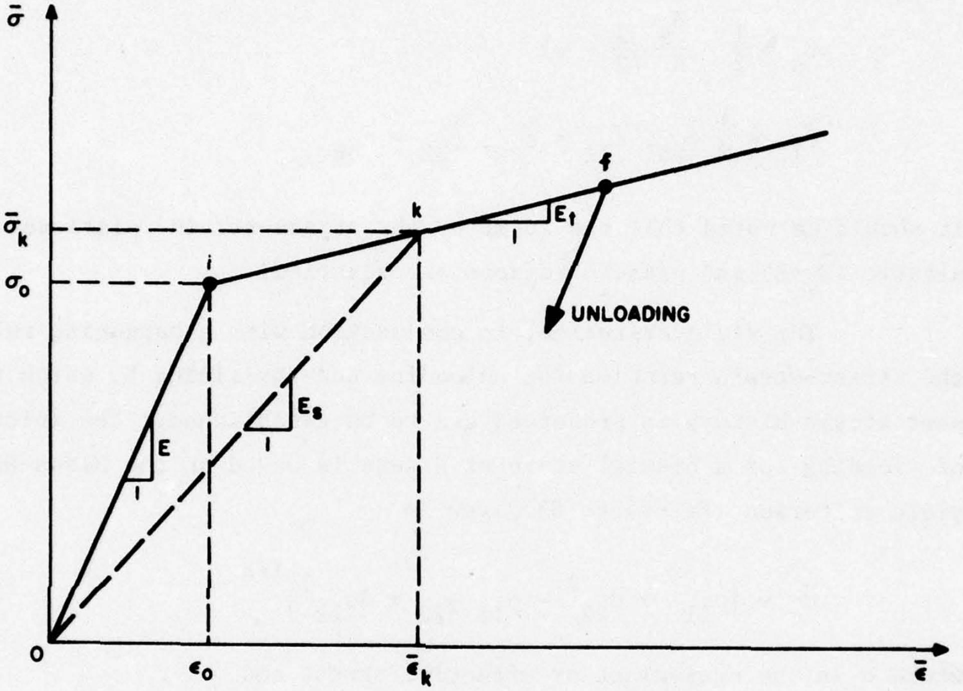


Figure 2. Effective Stress-Strain Bilinear Representation

into the form $\sigma_{ij} = f(\tilde{\varepsilon}_{ij})$ for the case of plane stress $(\sigma_{zz}=\sigma_{\theta z}=\sigma_{xz}=0)$, and are given by

$$\sigma_{ij} = \frac{E_s}{1-\nu_s^2}\left[(1-\nu_s)\tilde{\varepsilon}_{ij} + \nu_s\tilde{\varepsilon}_{kk}\delta_{ij}\right] \quad (i,j,k=1,2) \qquad (17)$$

where

$$\nu_s = \frac{1}{2} - \frac{E_s}{E}\left(\frac{1}{2} - \nu\right)$$

$$\tilde{\varepsilon}_{12} = \frac{1}{2}\tilde{\varepsilon}_{x\theta}, \quad \tilde{\varepsilon}_{11} = \tilde{\varepsilon}_{xx}, \quad \tilde{\varepsilon}_{22} = \tilde{\varepsilon}_{\theta\theta}$$

It should be noted that the forms of the stress-strain relations in the elastic (E_s=E) and plastic regions are identical.

The yield criterion, in conjunction with a hardening rule, and the stress-strain relation for unloading and reyielding by which the past strain history is preserved are to be established. The initiation of yielding for a biaxial state of stress is based on the Mises-Hencky yield criterion (Reference 6) given as

$$\bar{\sigma} = [\sigma_{11}^{2} + \sigma_{22}^{2} - \sigma_{11}\,\sigma_{22} + 3\sigma_{12}^{2}]^{1/2} \qquad (18)$$

where $\bar{\sigma}$ is the equivalent or effective stress and

$$\sigma_{11} = \sigma_{xx}, \quad \sigma_{22} = \sigma_{\theta\theta}, \quad \sigma_{12} = \sigma_{x\theta}$$

This yield criterion states that plastic flow will occur when the equivalent stress $\bar{\sigma}$ reaches a value equal to the uniaxial yield stress in tension σ_o. A kinematic hardening model is employed in conjunction with the Mises-Hencky yield surface which accounts for the Bauschinger effect when reyielding occurs due to the strain reversals during unloading. The Bauschinger effect for a strain hardening material is described by the yielding behavior of a material at a reduced yield stress when reloaded in the opposite direction from that of the initial yielding.

The kinematic hardening models discussed in Reference 7 assume that during plastic deformation the yield surface translates as a rigid body in stress space with the size, shape, and orientation of the elliptical yield surface being invariant. The kinematic hardening model to be used in this analysis is illustrated in Figure 3 for the Mises-Hencky yield surface in the plane of the principal stresses σ_1 and σ_2. Corresponding to the initial yielding position (i) and the unloading position (f) indicated in Figure 2, the rigid translation of the yield surface for a shift of the stress state from position (i) to position (f) is shown in Figure 3. The change in total stress components from position (i) to position (f) are defined by $\tilde{\alpha}_{ij}$ and, similarly, the corresponding change in the total strain components are defined by $\tilde{\beta}_{ij}$, so that

$$\tilde{\alpha}^{r}_{ij} = \tilde{\alpha}^{r-1}_{ij} + \sigma^{r-1}_{ij(f)} - \sigma^{r-1}_{ij(i)} \qquad (19)$$

$$\tilde{\beta}^{r}_{ij} = \tilde{\beta}^{r-1}_{ij} + \tilde{\varepsilon}^{r-1}_{ij(f)} - \tilde{\varepsilon}^{r-1}_{ij(i)}$$

where

r = the number of elastic unloadings from yielded conditions (r=1,2...)

$\tilde{\alpha}^{o}_{ij} = \tilde{\beta}^{o}_{ij} = 0$

(i) indicates initiation of yielding or reyielding

(f) indicates final position prior to unloading

The yield criterion for the translated yield surface is based on the effective stress given as

$$\bar{\sigma} = [(\sigma_{11}-\tilde{\alpha}^{r}_{11})^2 - (\sigma_{11}-\tilde{\alpha}^{r}_{11})(\sigma_{22}-\tilde{\alpha}^{r}_{22}) + (\sigma_{22}-\tilde{\alpha}^{r}_{22})^2 + 3(\sigma_{12}-\tilde{\alpha}^{r}_{12})^2]^{1/2} \qquad (20)$$

Furthermore, it is advantageous in this analysis to relocate the origin on the $\bar{\varepsilon}$ axis after each unloading such that the extended elastic

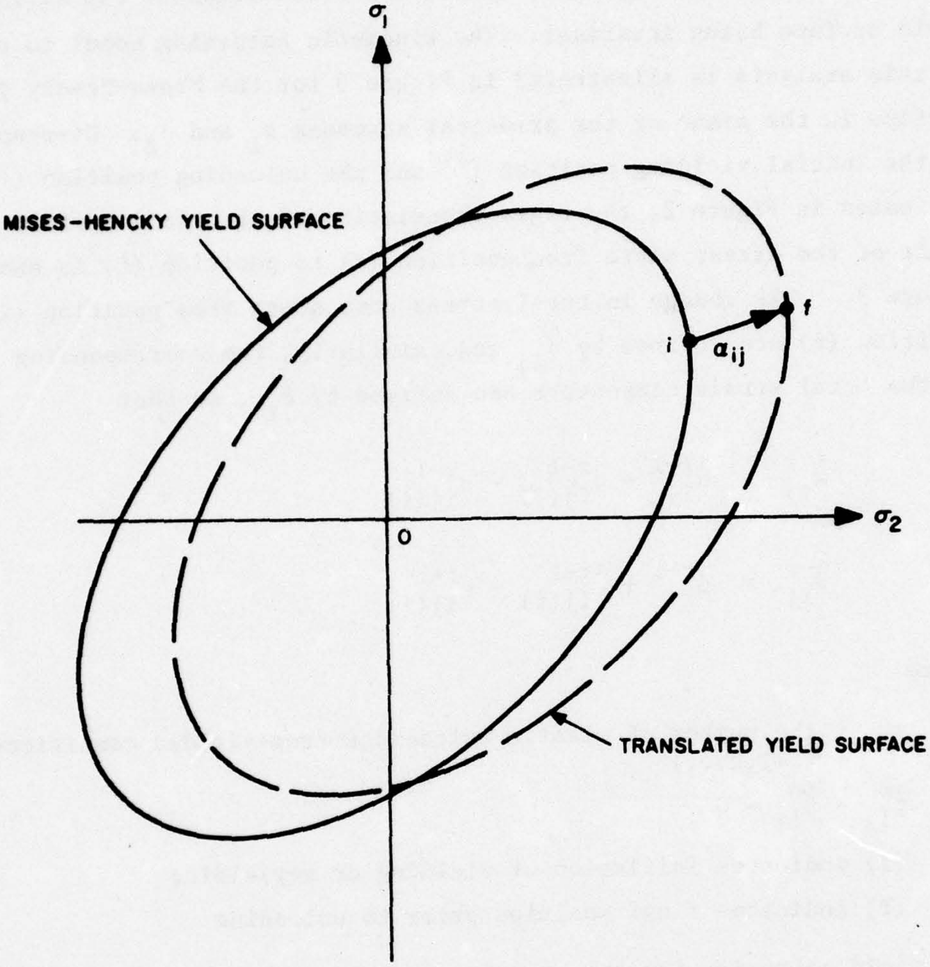


Figure 3. Kinematic Hardening Model

unloading curve passes through the zero position. This is accomplished by defining the effective strain as follows:

$$\bar{\varepsilon} = \left\{ \frac{1}{(1-\nu_s^2)^2} \left[(1-\nu_s+\nu_s^2)\left((\tilde{\varepsilon}_{11} - \tilde{\beta}^r_{11})^2 + (\tilde{\varepsilon}_{22}-\tilde{\beta}^r_{22})^2\right) - (1-4\nu_s+\nu_s^2)(\tilde{\varepsilon}_{11}-\tilde{\beta}^r_{11})(\tilde{\varepsilon}_{22}-\tilde{\beta}^r_{22}) \right] + \frac{3}{(1+\nu_s)^2}(\tilde{\varepsilon}_{12}-\tilde{\beta}^r_{12})^2 \right\}^{1/2} \qquad (21)$$

Thus, the elastic-plastic behavior of the material for subsequent yieldings after an unloading has occurred is always based on the same $\bar{\sigma}$ versus $\bar{\varepsilon}$ curve which originates at position (0,0). This approach requires that the stress-strain relations be modified by the $\tilde{\alpha}_{ij}$ and $\tilde{\beta}_{ij}$ quantities for unloading and reyielding conditions to account for the past stress-strain history. The general form of the stress-strain relations for the elastic, elastic-plastic, elastic unloading, and plastic reyielding regions are identical, so that the general stress-strain relations based on the form of Equation (17) is given by

$$\sigma_{ij} = \tilde{\alpha}^r_{ij} + \frac{E_s}{1-\nu_s^2}\left[(1-\nu_s)(\tilde{\varepsilon}_{ij}-\tilde{\beta}^r_{ij}) + \nu_s(\tilde{\varepsilon}_{kk}-\tilde{\beta}^r_{kk})\delta_{ij}\right] \qquad (22)$$

$$(i,j,k = 1,2)$$

where, for the following regions of response,

(a) initial elastic loading $E_s=E,\ \tilde{\alpha}^r_{ij} = \tilde{\beta}^r_{ij} = 0$

(b) initial plastic loading $E_s=E_s,\ \tilde{\alpha}^r_{ij} = \tilde{\beta}^r_{ij} = 0$

(c) qth elastic unloading $E_s=E\ ,\ \tilde{\alpha}^r_{ij} = \tilde{\alpha}^q_{ij},\ \tilde{\beta}^r_{ij} = \tilde{\beta}^q_{ij}$

(d) qth reyielding $\quad E_s = E_s,\ \tilde{\alpha}^r_{ij} = \tilde{\alpha}^q_{ij},\ \tilde{\beta}^r_{ij} = \tilde{\beta}^q_{ij}$

Thus, there are four basic regions of response for which the stress-strain relations have been established by Equation (22). For an elastic-perfectly plastic material, $E_t = 0$ and $\tilde{\alpha}^r_{ij}$ are set equal to zero in Equations (20) and (22). It should be noted that for a strain hardening material, a stress path which may move along the yield surface (neutral loading) would not be properly represented in the analysis, since, upon unloading, the yield surface would be rigidly translated.

For elastic, isotropic or orthotropic multilayered panels, the stress-strain relation formulation follows the approach presented in Reference 8. In orthotropic layers, the geometric cylindrical coordinate axes and principal orthotropic direction are assumed parallel. The multilayered cross section for the panel is shown in Figure 4 with the nomenclature used in the following formulation. The position of the coordinate surface relative to the inner surface of the panel is defined by the distance $\bar{H}$. The membrane and bending stress resultants for the multilayered panel are given by

$$\tilde{\sigma}^m_{xx} = C_{11}\varepsilon_{xx} + C_{12}\varepsilon_{\theta\theta} + F_{11}\kappa_{xx} + F_{12}\kappa_{\theta\theta} \tag{23a}$$

$$\tilde{\sigma}^m_{\theta\theta} = C_{22}\varepsilon_{\theta\theta} + C_{12}\varepsilon_{xx} + F_{22}\kappa_{\theta\theta} + F_{12}\kappa_{xx} \tag{23b}$$

$$\tilde{\sigma}^m_{x\theta} = C_{33}\varepsilon_{x\theta} + F_{33}\kappa_{x\theta} \tag{23c}$$

$$\tilde{\sigma}^b_{xx} = D_{11}\kappa_{xx} + D_{12}\kappa_{\theta\theta} + F_{11}\varepsilon_{xx} + F_{12}\varepsilon_{\theta\theta} \tag{23d}$$

$$\tilde{\sigma}^b_{\theta\theta} = D_{22}\kappa_{\theta\theta} + D_{12}\kappa_{xx} + F_{22}\varepsilon_{\theta\theta} + F_{12}\varepsilon_{xx} \tag{23e}$$

$$\tilde{\sigma}^b_{x\theta} = D_{33}\kappa_{x\theta} + F_{33}\varepsilon_{x\theta} \tag{23f}$$

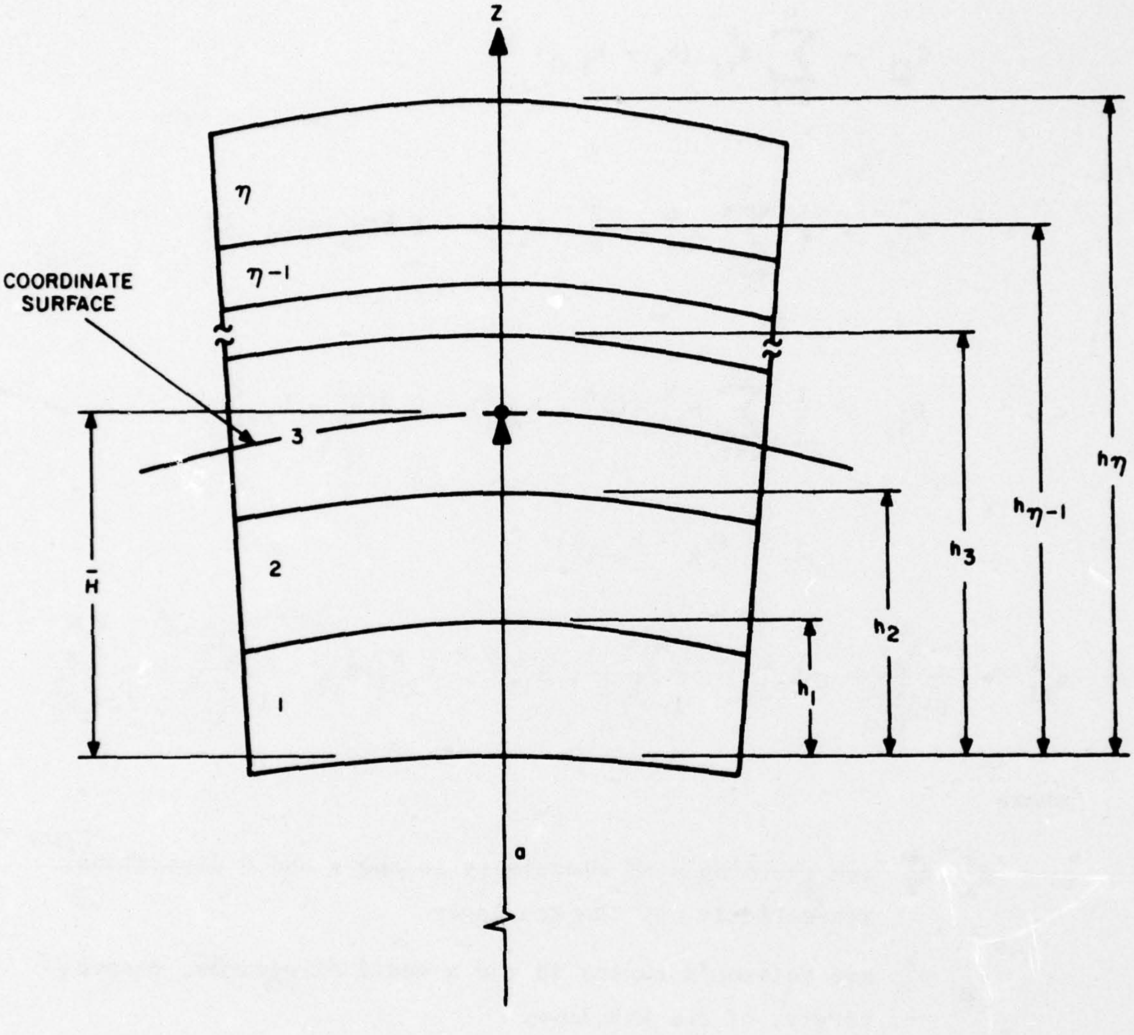


Figure 4. Multilayered Cross Section

The elastic stiffness constants C_{ij}, F_{ij} and D_{ij} are defined by

$$C_{ij} = \sum_{k=1}^{\eta} B_{ij}^{k} (h_k - h_{k-1})$$

$$F_{ij} = \frac{1}{2} \sum_{k=1}^{\eta} B_{ij}^{k} [(h_k^2 - h_{k-1}^2) - 2 \bar{H}(h_k - h_{k-1})]$$

$$D_{ij} = \frac{1}{3} \sum_{k=1}^{\eta} B_{ij}^{k} [(h_k^3 - h_{k-1}^3) - 3 \bar{H}(h_k^2 - h_{k-1}^2)$$
$$+ 3\bar{H}^2 (h_k - h_{k-1})]$$

$$B_{11}^{k} = \frac{E_x^k}{1-\nu_x^k \nu_\theta^k} , \quad B_{22}^{k} = \frac{E_\theta^k}{1-\nu_x^k \nu_\theta^k} , \quad B_{33}^{k} = G_{x\theta}^{k}, \quad B_{12}^{k} = \frac{\nu_x^k E_\theta^k}{1-\nu_x^k \nu_\theta^k} = \frac{\nu_\theta^k E_x^k}{1-\nu_x^k \nu_\theta^k}$$

where

E_x^k, E_θ^k	are the moduli of elasticity in the x and θ directions, respectively, of the kth layer
ν_x^k, ν_θ^k	are Poisson's ratios in the x and θ directions, respectively, of the kth layer
$G_{x\theta}^k$	is the shear modulus of the kth layer
h_k	is the distance from the inner shell surface to the outer surface of the kth layer
η	is the total number of layers

For an isotropic material $E_x = E_\theta = E$, $\nu_x = \nu_\theta = \nu$ and $G_{x\theta} = \frac{E}{2(1+\nu)}$.

It has been found that the optimal position of the coordinate surface for the most efficient modal convergence is at the neutral axis of the cross section. When the coordinate surface is located at the neutral axis, the interaction stiffnesses F_{ij} vanish. These interaction stiffnesses reflect the influence of the change in curvature on the membrane stress resultants and the membrane strains on the bending stress resultants. As discussed in Reference 8, for the general case of an antisymmetrical orthotropic multilayered cross section, a neutral axis, which is defined when all $F_{ij} = 0$, does not exist except for special combinations of elastic characteristics of the various layers. For the general case, the position of the coordinate axis, defined by $\bar{H}$, is established for this analysis by setting $F_{11} = F_{22} = F_{12} = F_{33} = 0$ to obtain the values

$$\bar{H}_{ij} = \frac{\sum_{k=1}^{n} B_{ij}^{k} (h_k^2 - h_{k-1}^2)}{2 \sum_{k=1}^{n} B_{ij}^{k} (h_k - h_{k-1})} \tag{24}$$

and then $\bar{H}$ is determined by averaging these values as follows:

$$\bar{H} = \frac{1}{4} (\bar{H}_{11} + \bar{H}_{22} + \bar{H}_{12} + \bar{H}_{33}) \tag{25}$$

It should be noted that for cases where the neutral axis does exist, the coordinate surface is located at this position through the above procedure. When the center of mass of the cross section does not coincide with the neutral axis, a slight discrepancy in the inplane inertia would be introduced since the rotary inertia is not included in this analysis.

2.4 Displacement Component Functions

In Equation (7) the displacement components are expressed in series form as a product of time-dependent coefficients and independent spatial functions $\phi_m(x)$ and $\phi_n(\theta)$. These spatial functions are selected so as to satisfy the geometric boundary conditions of the panels. The boundaries of the panel are assumed to be either clamped or simply supported and spatial functions are defined to cover all combinations of these boundary conditions for the four edges of a panel defined by $x = 0, \ell$ and $\theta = 0, \theta_o$. On clamped edges the boundary conditions

$$w = v = u = \frac{\partial w}{\partial x} = \frac{\partial w}{\partial \theta} = 0$$

are to be satisfied while on simply supported edges the boundary conditions

$$w = v = u = \frac{\partial^2 w}{\partial x^2} = \frac{\partial^2 w}{\partial \theta^2} = 0$$

are to be satisfied. Since the panels can be non-uniformly loaded, the assumed displacement functions contain both symmetrical and antisymmetrical modes. The nondimensional variables $\gamma = \frac{\pi x}{\ell}$ and $\beta = \frac{\pi \theta}{\theta_o}$ are introduced for use in this analysis. The spatial functions for the u and v displacements are assumed to be the same whether the edges are clamped or simply supported and are given by

$$\phi_m^u(\gamma) = \sin\,(m + 1)\gamma$$

$$\phi_n^u(\beta) = \sin n\beta \qquad (26)$$

$$\phi_m^v(\gamma) = \sin m\gamma$$

$$\phi_n^v(\beta) = \sin\,(n + 1)\beta$$

The boundary combinations for the γ and β directions are based on opposite edges being both clamped, both simply supported or one clamped and one simply supported. The w-displacement functions for the γ and β directions are based on the natural vibratory mode shapes of a uniform beam with corresponding end boundary conditions. These spatial functions in the γ and β directions are given as follows for the three boundary combinations:

For clamped/clamped or clamped/simply supported edges

$$\phi_m^w = \cosh\frac{\lambda_m\gamma}{\pi} - \cos\frac{\lambda_m\gamma}{\pi} - \alpha_m\left(\sinh\frac{\lambda_m\gamma}{\pi} - \sin\frac{\lambda_m\gamma}{\pi}\right) \qquad (27)$$

$$\phi_n^w = \cosh\frac{\lambda_n\beta}{\pi} - \cos\frac{\lambda_n\beta}{\pi} - \alpha_n\left(\sinh\frac{\lambda_n\beta}{\pi} - \sin\frac{\lambda_n\beta}{\pi}\right)$$

where

λ_m or λ_n are the roots of $\cos\lambda_i \cosh\lambda_i = 1$ for the clamped/ clamped boundary condition

λ_m or λ_n are the roots of $\tan\lambda_i = \tanh\lambda_i$ for the clamped/ simply supported boundary condition

$$\alpha_i = \frac{\cosh\lambda_i - \cos\lambda_i}{\sinh\lambda_i - \sin\lambda_i}$$

$$i = n \text{ or } m$$

For opposite edges simply supported

$$\phi_m^w = \sin m\gamma \qquad (28)$$

$$\phi_n^w = \sin n\beta$$

It should be noted that the functions given in Equations (27) and 28) are orthogonal.

For the general cylindrical panel, there are nine combinations of boundary conditions provided by the DEPROP program, namely,

	γ-direction	β-direction
1.	C-C	C-C
2.	S-S	S-S
3.	C-C	S-S
4.	S-S	C-C
5.	C-S	C-C
6.	C-C	C-S
7.	C-S	S-S
8.	S-S	C-S
9.	C-S	C-S

2.5 Governing Equations of Motion

With the strain-displacement relations [Equations (13) and (14)], the stress-strain relations [Equations (22) and (23)] and the displacement component functions [Equations (26) to (28)] defined, the governing equations of motion [Equation (10)] for elastic-plastic deformations are developed further by performing the indicated spatial integrations. For convenience, the dimensionless quantities $W = \frac{w}{a}$, $V = \frac{v}{a}$, $U = \frac{u}{a}$, $\overset{\circ}{W} = \frac{\overset{\circ}{w}}{a}$, $\gamma = \frac{\pi x}{\ell}$, $\beta = \frac{\pi\theta}{\theta_o}$, $L = \frac{\ell}{\pi a}$, $J = \frac{\pi}{\theta_o}$, $R = \frac{a}{h}$, and $K = \kappa a$ are introduced into the formulations. With this notation and the spatial integration for the kinetic energy in Equation (12) performed analytically, the governing equations of motion in the radial displacement direction [Equation (10c)] are given by

$$k_\gamma k_\beta \rho \ell^2 \ddot{W}_{mn} + \frac{2L^2}{h} \int_o^\pi \int_o^\pi \int_{-h/2}^{h/2} \sigma_{ij} \frac{\partial \tilde{\varepsilon}_{ij}}{\partial W_{mn}} d\gamma d\beta dz - \int_o^\pi \int_o^\pi \tilde{Q}_w d\gamma d\beta = 0$$

$$(m=1,2,\ldots M)$$
$$(n=1,2,\ldots N) \qquad (29)$$

where for the w-equations

$k_\gamma, k_\beta \ \sqrt{2}$ for C-C or C-S opposite boundaries

$= 1/\sqrt{2}$ for S-S opposite boundaries,

for the u and v-equations

$k_\gamma = k_\beta = 1/\sqrt{2}$

and

$$\tilde{Q}_w = 2L^2 Rp(1 - \lambda W - \lambda \mathring{W} + JV_\beta + \frac{1}{L} U_\gamma) \frac{\partial W}{\partial W_{mn}}$$
$$\tilde{Q}_v = -2L^2 Rp(JW_\beta + J\mathring{W}_\beta + \lambda V) \frac{\partial V}{\partial V_{mn}} \qquad (30)$$
$$\tilde{Q}_u = -2LRp(W_\gamma + \mathring{W}_\gamma) \frac{\partial U}{\partial U_{mn}}$$

Although Equation (29) is given in terms W_{mn}, the equations of motion for the tangential and axial displacement directions can be obtained by replacing W_{mn} with V_{mn} and U_{mn}, respectively, and using the appropriate k_γ, k_β, and $\tilde{Q}$ expressions.

The remaining spatial integrations in Equation (29) are to be accomplished numerically, thus providing a mechanism for discretization through the spatial points selected to compute the representative elastic-plastic behavior throughout the panel. Thus, a sufficient number of spatial points must be specified to obtain a satisfactory deformation response solution. For integration through the thickness of the panel in the z direction, it is convenient to separate the integrand into parts which either are or are not explicitly dependent on the z variable, that is, involving membrane strains and bending strains. The total strain quantities $\tilde{\varepsilon}_{ij}$ given in Equation (29) for an arbitrary position in the panel consist of the membrane and bending components given by

$$\tilde{\varepsilon}_{ij} = \varepsilon_{ij} + z\kappa_{ij} \tag{31}$$

Therefore, the integrand can be given by $f^m + zf^b$ where

$$f^m = \sigma_{xx} \frac{\partial \varepsilon_{xx}}{\partial W_{mm}} + \sigma_{\theta\theta} \frac{\partial \varepsilon_{\theta\theta}}{\partial W_{mn}} + \sigma_{x\theta} \frac{\partial \varepsilon_{x\theta}}{\partial W_{mn}} \tag{32a}$$

$$f^b = \sigma_{xx} \frac{\partial K_{xx}}{\partial W_{mn}} + \sigma_{\theta\theta} \frac{\partial K_{\theta\theta}}{\partial W_{mn}} + \sigma_{x\theta} \frac{\partial K_{x\theta}}{\partial W_{mn}} \tag{32b}$$

and the total stress components are obtained from Equations (22) and (19) in which i,j=1 denotes x and i,j=2 denotes θ. The Legendre-Gauss quadrature formula (Reference 9) was chosen for the numerical integration in the z direction where $\bar{L}$ is the number of points selected through the thickness of the panel. In the γ and β directions it is convenient to have even spacing, and it is advantageous to have spatial points on the clamped edges and at the center of the panel. Simpson's quadrature formula (Reference 9) possesses these desirable features and therefore was selected over various Gaussian quadrature formulas. The number of spatial points selected in the γ and β directions are given by $\bar{M}$ and $\bar{N}$, respectively, where $\bar{M}$ and $\bar{N}$ must be odd numbers. By performing the indicated numerical integrations, Equation (29) is recast into the form:

$$k_\gamma k_\beta \rho \ell^2 \ddot{W}_{mn} + \frac{\pi^2}{9(\bar{M}-1)(\bar{N}-1)} \sum_{j=1}^{\bar{M}} \sum_{k=1}^{\bar{N}} H_j H_k \left\{ L^2 \sum_{i=1}^{\bar{L}} H_i \left[f_i^m(\gamma_j, \beta_k) \right.\right.$$

$$\left.\left. + \frac{1}{2R} \xi_i f_i^b (\gamma_j, \beta_k) \right] - \tilde{Q}_w (\gamma_j, \beta_k) \right\} = 0 \qquad (33)$$

$(m=1,2\ldots M)$

$(n=1,2\ldots N)$

where

ξ_i are the zeros of the Legendre polynomial $P_{\bar{L}} (\xi)$

$$z_i = \frac{h}{2} \xi_i$$

$$H_i = \frac{2(1-\xi_i^2)}{(\bar{L}+1)^2 \; [P_{\bar{L}+1}(\xi_i)]^2}$$

$H_{j \text{ or } k} = 4$ (j,k = even)

$= 2$ (j,k = odd, except for $j=1, \bar{M}$ or $k = 1,\bar{N}$)

$= 1$ ($j=1, \bar{M}$ and $k=1,\bar{N}$)

$$\gamma_j = \left(\frac{j-1}{\bar{M}-1}\right)\pi$$

$$\beta_k = \left(\frac{k-1}{\bar{N}-1}\right)\pi$$

When symmetry is present in both the γ and β direction, for example, only one-quarter of the panel need be considered and the spatial integration takes the form

$$4 \int_{0}^{\pi/2} \int_{0}^{\pi/2} F(\gamma,\beta) d\gamma d\beta = \frac{4\pi^2}{9(\bar{M}-1)(\bar{N}-1)} \sum_{j=1}^{\frac{\bar{M}+1}{2}} c_j H_j \sum_{k=1}^{\frac{\bar{N}+1}{2}} d_k H_k F(\gamma_j,\beta_k) \tag{34}$$

where

$$c_j = 1 \qquad j = 1, 2, \ldots \frac{\bar{M}-1}{2}$$

$$= \frac{1}{2} \qquad j = \frac{\bar{M}+1}{2}$$

$$d_k = 1 \qquad k = 1, 2, \ldots \frac{\bar{N}-1}{2}$$

$$= \frac{1}{2} \qquad k = \frac{\bar{N}+1}{2}$$

For the purely elastic solution of a panel, the integrations through the thickness can be obtained analytically, and results in the following simplification in Equation (33):

$$\sum_{i=1}^{\bar{L}} H_i f_i^m = 2f^m \quad , \quad \sum_{i=1}^{\bar{L}} H_i \xi_i f_i^b = \frac{1}{3R} f^b \tag{35}$$

where σ^m_{ij} replaces σ_{ij} in f^m [Equation (32a)], $\sigma_{ij}{}^b$ replaces σ_{ij} in f^b [Equation (32b)] and

$$\sigma^m_{ij} = \frac{E}{1-\nu^2}\left[(1-\nu)\varepsilon_{ij} + \nu\varepsilon_{kk}\delta_{ij}\right] \tag{36a}$$

$$\sigma_{ij}{}^b = \frac{E}{1-\nu^2}\left[(1-\nu)K_{ij} + \nu K_{kk}\delta_{ij}\right] \tag{36b}$$

$$(i,j,k = 1,2)$$

The quantities ε_{xx}, $\varepsilon_{\theta\theta}$ and $\varepsilon_{x\theta}$ are given by the normalized versions of Equations (13) and

$$\frac{\partial\varepsilon_{xx}}{\partial U_{mn}} = \frac{1}{L}\left[\frac{\partial U_\gamma}{\partial U_{mn}} + \frac{1}{L}\;U_\gamma\,\frac{\partial U_\gamma}{\partial U_{mn}}\right] \tag{37a}$$

$$\frac{\partial\varepsilon_{xx}}{\partial V_{mn}} = \frac{1}{L^2}\,V_\gamma\,\frac{\partial V_\gamma}{\partial V_{mn}} \tag{37b}$$

$$\frac{\partial\varepsilon_{xx}}{\partial W_{mn}} = \frac{1}{L^2}\left[W_\gamma\,\frac{\partial W_\gamma}{\partial W_{mn}} + \overset{\circ}{W}_\gamma\,\frac{\partial W_\gamma}{\partial W_{mn}}\right] \tag{37c}$$

$$\frac{\partial\varepsilon_{\theta\theta}}{\partial U_{mn}} = J^2U_\beta\,\frac{\partial U_\beta}{\partial U_{mn}} \tag{37d}$$

$$\frac{\partial \varepsilon_{\theta\theta}}{\partial V_{mn}} = J \frac{\partial V_{\beta}}{\partial V_{mn}} + \lambda J W_{\beta} \frac{\partial V}{\partial V_{mn}} + \lambda V \frac{\partial V}{\partial V_{mn}} + J^{2} V_{\beta} \frac{\partial V_{\beta}}{\partial V_{mn}} - \lambda J W \frac{\partial V_{\beta}}{\partial V_{mn}} \tag{37e}$$

$$\frac{\partial \varepsilon_{\theta\theta}}{\partial W_{mn}} = -\lambda \frac{\partial W}{\partial W_{mn}} + J^{2} W_{\beta} \frac{\partial W_{\beta}}{\partial W_{mn}} + J^{2} \mathring{W}_{\beta} \frac{\partial W_{\beta}}{\partial W_{mn}} + \lambda J V \frac{\partial W_{\beta}}{\partial W_{mn}}$$

$$-J\lambda V_{\beta} \frac{\partial W}{\partial W_{mn}} + \lambda W \frac{\partial W}{\partial W_{mn}} \tag{37f}$$

$$\frac{\partial \varepsilon_{x\theta}}{\partial U_{mn}} = J \frac{\partial U_{\beta}}{\partial U_{mn}} + \frac{J U_{\beta}}{L} \frac{\partial U_{\gamma}}{\partial U_{mn}} + \frac{J U_{\gamma}}{L} \frac{\partial U_{\beta}}{\partial U_{mn}} \tag{37g}$$

$$\frac{\partial \varepsilon_{x\theta}}{\partial V_{mn}} = \frac{1}{L} \left[\frac{\partial V_{\gamma}}{\partial V_{mn}} + \lambda W_{\gamma} \frac{\partial V}{\partial V_{mn}} + J V_{\gamma} \frac{\partial V_{\beta}}{\partial V_{mn}} + J V_{\beta} \frac{\partial V_{\gamma}}{\partial V_{mn}} - \lambda W \frac{\partial V_{\gamma}}{\partial V_{mn}} \right] \tag{37h}$$

$$\frac{\partial \varepsilon_{x\theta}}{\partial W_{mn}} = \frac{1}{L} \left[J W_{\gamma} \frac{\partial W_{\beta}}{\partial W_{mn}} + J W_{\beta} \frac{\partial W_{\gamma}}{\partial W_{mn}} + J \mathring{W}_{\gamma} \frac{\partial W_{\beta}}{\partial W_{mn}} + J \mathring{W}_{\beta} \frac{\partial W_{\gamma}}{\partial W_{mn}} \right.$$

$$\left. + \lambda V \frac{\partial W_{\gamma}}{\partial W_{mn}} - \lambda V_{\gamma} \frac{\partial W}{\partial W_{mn}} \right] \tag{37i}$$

The quantities K_{xx}, $K_{\theta\theta}$ and $K_{x\theta}$ are given by the normalized versions of Equations (14) and

$$\frac{\partial K_{xx}}{\partial U_{mn}} = \frac{1}{L^{3}} W_{\gamma\gamma} \frac{\partial U_{\gamma}}{\partial U_{mn}} \tag{38a}$$

$$\frac{\partial K_{xx}}{\partial V_{mn}} = \frac{J}{L^2} W_{\gamma\gamma} \frac{\partial V_\beta}{\partial V_{mn}} \tag{38b}$$

$$\frac{\partial K_{xx}}{\partial W_{mn}} = \frac{1}{L^2}\left(1 + JV_\beta + \frac{1}{L} U_\gamma - \lambda W\right) \frac{\partial W_{\gamma\gamma}}{\partial W_{mn}} - \frac{\lambda}{L^2} W_{\gamma\gamma} \frac{\partial W}{\partial W_{mn}} \tag{38c}$$

$$\frac{\partial K_{\theta\theta}}{\partial U_{mn}} = \lambda\frac{1}{L} \frac{\partial U_\gamma}{\partial U_{mn}} + \frac{J^2}{L} W_{\beta\beta} \frac{\partial U_\gamma}{\partial U_{mn}} \tag{38d}$$

$$\begin{aligned} \frac{\partial K_{\theta\theta}}{\partial V_{mn}} &= (2\lambda J + J^3 W_{\beta\beta} + 4\lambda J^2 V_\beta - 3\lambda JW) \frac{\partial V_\beta}{\partial V_{mn}} \\ &\quad + \lambda(3JW_\beta + 2V) \frac{\partial V}{\partial V_{mn}} \end{aligned} \tag{38e}$$

$$\begin{aligned} \frac{\partial K_{\theta\theta}}{\partial W_{mn}} &= \left(J^2 + J^3 V_\beta - \lambda J^2 W + \frac{J^2}{L} U_\gamma\right) \frac{\partial W_{\beta\beta}}{\partial W_{mn}} \\ &\quad + (-\lambda + 2\lambda W - 3\lambda JV_\beta - \lambda J^2 W_{\beta\beta}) \frac{\partial W}{\partial W_{mn}} \\ &\quad + \lambda(4J^2 W_\beta + 3JV) \frac{\partial W_\beta}{\partial W_{mn}} \end{aligned} \tag{38f}$$

$$\frac{\partial K_{x\theta}}{\partial U_{mn}} = \frac{2J}{L^2} W_{\gamma\beta} \frac{\partial U_\gamma}{\partial U_{mn}} \tag{38g}$$

$$\frac{\partial K_{x\theta}}{\partial V_{mn}} = \lambda\frac{1}{L} \frac{\partial V_\gamma}{\partial V_{mn}} + \frac{2J^2}{L} W_{\gamma\beta} \frac{\partial V_\beta}{\partial V_{mn}} + \frac{2\lambda}{L} W_\gamma \frac{\partial V}{\partial V_{mn}} \tag{38h}$$

$$\frac{\partial K_{x\theta}}{\partial W_{mn}} = \frac{2J}{L}\left(1 + JV_{\beta} + \frac{1}{L}U_{\gamma} - \lambda W\right)\frac{\partial W_{\gamma\beta}}{\partial W_{mn}} - \frac{2\lambda J}{L}W_{\gamma\beta}\frac{\partial W}{\partial W_{mn}}$$

$$+ \frac{2\lambda}{L}(JW_{\beta} + V)\frac{\partial W_{\gamma}}{\partial W_{mn}} + \frac{2\lambda J}{L}W_{\gamma}\frac{\partial W_{\beta}}{\partial W_{mn}} \qquad (38i)$$

For the elastic response solution of multilayered panels, the same formulation is used with several modifications. The stiffness constants in Equation (23), C_{ij}, F_{ij} and D_{ij}, are considered to have been divided by a, a^2 and a^3, respectively, and $R = a/h_{\eta}$. In Equation (33), ρ is replaced by $\bar{\rho}$ given by

$$\bar{\rho} = \frac{1}{h_{\eta}}\sum_{k=1}^{\eta}\rho_k\,(h_k - h_{k-1})$$

and

$$\sum_{i=1}^{\bar{L}} H_i f_i^m = 2Rf^m$$

$$\sum_{i=1}^{\bar{L}} H_i \xi_i f_i^b = 4R^2 f^b$$

The $\tilde{\sigma}^m$ and $\tilde{\sigma}^b$ quantities given in Equation (23) replace the appropriate total stress quantities given in Equation (32). With these modifications in DEPROP, elastic response solutions can be obtained for multilayered panels of isotropic or orthotropic material layers.

2.6 Numerical Analysis

The second-order differential equations given by Equation (33) and corresponding equations for V_{mn} and U_{mn} are to be solved numerically in time. The integration method used to obtain an approximate timewise step-by-step solution is based on the central difference formula given by

$$X_{k+1} = \ddot{X}_k (\Delta t)^2 + 2X_k - X_{k-1} \tag{39}$$

where

X represents the normalized undetermined time-dependent displacement coefficients, W_{mn}, V_{mn} and U_{mn}

Δt is the time increment

k denotes the time step

In solving the set of simultaneous second-order differential equations, spatial integrations must be performed in the γ and β directions and in the z direction for the elastic-plastic solution during the stepwise time integration. The required integrations are performed numerically during each time step using the values of the displacement coefficients W_{mn}, V_{mn}, and U_{mn} for the particular time step to compute the displacements and their derivatives, the strain quantities, and the stress quantities used in Equation (33).

Several situations arise in the implementation of the biaxial elastic-plastic theory in DEPROP which require special numerical treatment. These situations are associated with the overshoot during the time increment in which yielding occurs, the criteria for determining elastic unloading and restrictions if unloading is followed by immediate reyielding, and the consistent determination of $\bar{\varepsilon}$, E_s, ν_s, and σ_{ij} during each time step. The special numerical schemes used to treat these three situations are described briefly in the following three paragraphs, respectively.

Whenever a point in the panel yields or reyields during a time increment ($\bar{\sigma} > \sigma_o$), the stresses cannot, in general, be computed on a purely elastic basis. The computation of stresses should follow the bilinear stress-strain curve, but this is very difficult to effect since $\bar{\sigma}$ is not a linear function of the σ_{ij}'s. Instead, an iterative scheme is employed to adjust the σ_{ij}'s proportionately, so that $\bar{\sigma} \cong \sigma_o$. By elastic relations, the associated strains ε_{ij} (σ_{ij}) are then determined for the later computation of $\tilde{\beta}_{ij}$ [Equation (19)]. The process for correcting for overshoot when yielding occurs between times t_{k-1} and t_k is illustrated in Figure 5. The values of $\bar{\varepsilon}$ and $\bar{\sigma}$ are shown at time t_{k-1}; the values indicated at t_k represent hypothetical uncorrected values. By linearly adjusting the stresses, the point ($\bar{\varepsilon}_o$, $\bar{\sigma}_o$) is reached. It is noted that the actual point at time t_k should be ($\bar{\varepsilon}_k$, $\bar{\sigma}_A$) instead of ($\bar{\varepsilon}_k$, $\bar{\sigma}_o$), but the error in stress is relatively small since $E_t/E << 1$. The error introduced is proportional to the size of the integration time step used.

For a point in the panel which is yielding at time t_{k-1}, elastic unloading is detected when, in proceeding to the next time t_k, the equivalent strain decreases, i.e., $\bar{\varepsilon}_k < \bar{\varepsilon}_{k-1}$. When this occurs, $\bar{\varepsilon}_k$ and $\bar{\sigma}_k$ are recomputed using the elastic unloading version of Equation (22). Furthermore, unless $\bar{\sigma}_k$ is less than $\bar{\sigma}_{k-1}$, it is assumed that the point did not unload. This possible inconsistency is partially numerical in nature and is partially due to the nonlinearity of the Equations

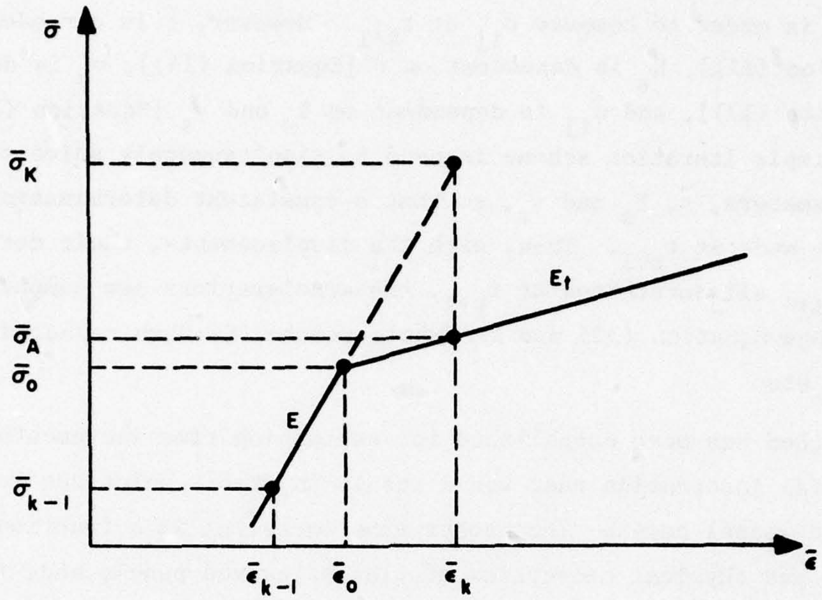


Figure 5. Correction for Overshoot at Yielding

(20) or (21). However, only rarely will a point pass the strain criterion for unloading but fail the stress criterion. Due to numerical discrepancies, it is possible for the computed $\bar{\sigma}_k$ in the unloading region to be greater than σ_o at time t_k. This inconsistency results in reyielding without any overshoot correction being made. In fact, this event represents a numerical error and is usually associated with the initial stages of numerical instability of the solution. Consequently, if this event frequently occurs, the run is automatically terminated and a smaller time increment must be selected.

In the temporal integration sequence, the displacement coefficients are computed for the end of the next time step at t_{k+1} through the central-difference formula [Equation (39)] given the past displacement coefficients at t_k and t_{k-1} and the acceleration at t_k. These extrapolated displacement coefficients are then used to compute ϵ_{ij} at t_{k+1}. Then, for points in the plastic region, the quantities $\bar{\epsilon}$, E_s, and ν_s are evaluated in order to compute σ_{ij} at t_{k+1}. However, $\bar{\varepsilon}$ is dependent on ν_s [Equation (21)], E_s is dependent on $\bar{\varepsilon}$ [Equation (15)], ν_s is dependent on E_s [Equation (17)], and σ_{ij} is dependent on E_s and ν_s [Equation (22)]. Thus, a simple iteration scheme is used to simultaneously solve for the three parameters, $\bar{\varepsilon}$, E_s and ν_s, so that a consistent determination of σ_{ij} can be made at t_{k+1}. Then, with the displacements, their derivatives, ε_{ij} and σ_{ij}, all determined at t_{k+1}, the accelerations are computed at t_{k+1} through Equation (33) and the whole process is then repeated for the next time step.

A method has been established for estimating time increments Δt for the temporal integration that would result in stable solutions for the majority of panel cases. The proper time increment is a function of geometric and physical properties of flat or curved panels and, for the DEPROP formulation, also a function of the number of modes used and the spacing between spatial integration points. The method for estimating time increments is based on formulas for the higher vibratory frequencies of linear elastic panels which incorporate the aforementioned parameters. The basic frequency formulas for single-layered flat and curved panels were obtained from References 10 and 11 and modified for multilayered panels. The time increment is estimated by the product of the reciprocal of the frequency and an arbitrary adjustment factor. Large displacement and/or elastic-plastic panel responses are nonlinear so that the arbitrary adjustment factors are determined by back-figuring from the time increments found to give stable solutions for various representative panels. In some panel cases considered where the spacing between integration points were critical for numerical stability, it was found that the Δt formula used for finite difference solutions is applicable. This formula is based on the time for an inplane elastic wave to propagate between mesh points.

For flat panels the governing time increment used as the initial estimate for Δt in DEPROP solutions is the smaller Δt obtained from the following two formulas. The first formula is associated with the highest solution frequency of a flat panel with inplane stresses which are assumed to be at a level corresponding to yield or ultimate stress of the panel material and is given by

$$\Delta t_1 = \frac{\pi}{25}\left\{\frac{D_{22}\lambda_{mn}^2}{\sum_{k=1}^{\eta} \rho_k \, (h_k - h_{k-1})} + \frac{\sum_{k=1}^{\eta} \sigma_{max}(h_k - h_{k-1})}{\sum_{k=1}^{\eta} \rho_k \, (h_k - h_{k-1})} \lambda_{mn}\right\}^{-1/2} \tag{40}$$

where

$\lambda_{mn} = \left(\frac{\bar{m}\pi}{\ell}\right)^2 + \left(\frac{\bar{n}\pi}{b}\right)^2$

σ_{max} = yield or ultimate stress

$\bar{m} = m+c$

$\bar{n} = n+c$

and c=0, 0.15, and 0.3 for S-S, S-C, and C-C boundary conditions, respectively. The second formula is associated with the elastic wave propogation between integration points in the short direction and is given by

$$\Delta t_2 = \frac{b}{\bar{N}-1}\left[\frac{\sum_{k=1}^{\eta} \rho_k \, (h_k - h_{k-1})}{C_{22}}\right]^{1/2} \tag{41}$$

For curved cylindrical panels the smallest Δt obtained from five formulas is used for the initial estimate for DEPROP solutions. The first two formulas are associated with high frequency modes of cylindrical shells and are given by

$$\Delta t_1 = \frac{\pi a}{35} \left[\frac{\sum_{k=1}^{\eta} \rho_k (h_k - h_{k-1})}{C_{22}} \right]^{1/2} \left\{ \frac{1+\bar{\lambda}^2}{2} - \frac{1}{2} \left[(1-\bar{\lambda}^2) + 4\nu^2 \bar{\lambda}^2 \right]^{1/2} \right\}^{-1/2} \tag{42}$$

$$\Delta t_2 = \frac{\pi a}{35} \left\{ \frac{D_{22}(\bar{k}^2+\bar{\lambda}^2)^2}{a^2 \sum_{k=1}^{\eta} \rho_k (h_k - h_{k-1})} + \frac{\bar{\lambda}^4 C_{22}}{(\bar{k}^2+\bar{\lambda}^2)^2 \sum_{k=1}^{\eta} \rho_k (h_k - h_{k-1})} \right\}^{-1/2} \tag{43}$$

where

$$\bar{\lambda} = \frac{\bar{m}\pi a}{\ell}$$

$$\bar{k} = \frac{\bar{n}\pi}{\theta_o}$$

The third formula is associated with the elastic wave propagation between integration points in the θ-direction and is given by

$$\Delta t_3 = \frac{a\theta_o}{\bar{N}-1}\left[\frac{\sum_{k=1}^{\eta} \rho_k(h_k-h_{k-1})}{C_{22}}\right]^{1/2} \qquad (44)$$

In cases where the length of the panel in the x-direction is much shorter than the arc length in the θ-direction, it was found that the flat panel formulas were more applicable than the above three formulas. Thus, the fourth and fifth formulas used are based on Equations (40) and (41) with changing D_{22} to D_{11} and b to $a\theta_o$ in Equation (40), and b to ℓ, $\bar{N}$ to $\bar{M}$ and C_{22} to C_{11} in Equation (41).

The smallest time increment obtained from the modified formulas used for either flat or curved panels represents an estimated value that will generally give a stable solution, but does not necessarily represent an optimal value for minimizing computer time. If a stable solution is obtained with this estimated time increment, the time increment can be increased until two consecutive solutions disagree significantly and the penultimate time increment selected for future computer time optimization, if desired. If the solution diverges using the initial estimated time increment from the formula procedure, halving the time increment should easily result in a solution in the stable range. The DEPROP program provides the option of automatically using the above estimated time increment or having the user select a value.

2.7 Boundary Reaction Forces

The reaction forces normal and tangent to the coordinate surface along the boundaries of the panel are determined in DEPROP so that the loads on the panel fasteners can be estimated if desired. The normal reaction forces per unit length for a clamped or simply supported cylindrical panel, V_x and V_θ, are given in Reference 12 by

$$V_x = \left(\frac{\partial M_x}{\partial x} - 2 \frac{\partial M_{x\theta}}{a\partial\theta} \right)_{x = \ell}$$

$$V_\theta = \left(\frac{\partial M_\theta}{a\partial\theta} - 2 \frac{\partial M_{x\theta}}{\partial x} \right)_{\theta = \theta_o} \tag{45}$$

where the resultant moments are given by

$$M_x = \int_{-h/2}^{h/2} \sigma_{xx} z dz, \quad M_\theta = \int_{-h/2}^{h/2} \sigma_{\theta\theta} z dz, \quad M_{x\theta} = -\int_{-h/2}^{h/2} \sigma_{x\theta} z dz \tag{46}$$

In addition, there are concentrated reaction forces acting at the corners of the simply supported panel, and they are given by

$$\bar{R} = 2M_{x\theta}, \tag{47}$$

The tangential reaction forces per unit length along the boundaries are given by

$$N_x = \int_{-h/2}^{h/2} \sigma_{xx}\, dz$$

$$N_\theta = \int_{-h/2}^{h/2} \sigma_{\theta\theta}\, dz \tag{48}$$

For the elastic solution of the general orthotropic multilayered panel, the reaction forces are computed in DEPROP from the following expressions:

$$\bar{V}_x = D_{11} w_{xxx} + \frac{1}{a^2} (D_{12} + 4D_{33}) w_{\theta\theta x} \tag{49a}$$

$$V_x\ (x = o) = -\bar{V}_x\ (x = \alpha)\ ;\ V_x\ (x = \ell) = \bar{V}_x\ (x = \ell)$$

$$\bar{V}_\theta = \frac{1}{a^3} D_{22} w_{\theta\theta\theta} + \frac{1}{a} (D_{12} + 4D_{33}) w_{xx\theta} \tag{49b}$$

$$V_\theta (\theta = o) = -\bar{V}_\theta\ (\theta = o)\ ;\ V_\theta\ (\theta = \theta_o) = \bar{V}_\theta\ (\theta = \theta_o)$$

$$\bar{R}\ (x,\theta = o,o;\ \ell,\theta_o) = -\frac{4}{a} D_{33} w_{x\theta} \tag{49c}$$

$$\bar{R}\ (x,\theta = o,\theta_o;\ \ell,o) = \frac{4}{a} D_{33} w_{x\theta}$$

$$N_x = C_{11}\varepsilon_{xx} + C_{12}\varepsilon_{\theta\theta} \quad (x = o,\ell) \tag{49d}$$

$$N_\theta = C_{22}\varepsilon_{\theta\theta} + C_{12}\varepsilon_{xx} \quad (\theta = o,\theta_o) \tag{49e}$$

It should be noted that for Equations (49a) through (49c) the nonlinear terms of the bending strains have been neglected in the determination of the normal reaction forces.

In the elastic-plastic solution, the inelastic stresses are complicated nonlinear functions of strain. Therefore, the partial derivatives indicated in Equation (45) cannot readily be determined as they were for the elastic case. If these derivatives are determined through finite difference expressions, however, the complexity of the program is not unduly increased and the reaction forces are obtained from stress quantities already computed in the solution at the spatial integration points on and adjacent to the boundaries of the panel. Thus, the normal reaction forces for the elastic-plastic solution are computed in DEPROP from the following expressions:

$$V_x = \frac{M_x^{\bar{M}} - M_x^{\bar{M}-1}}{\Delta x} - 2\,\frac{M_{x\theta}^{k} - M_{x\theta}^{k-1}}{a\Delta\theta} \quad (x = \ell) \qquad (50a)$$

$$V_\theta = \frac{M_\theta^{\bar{N}} - M_\theta^{\bar{N}-1}}{a\Delta\theta} - 2\,\frac{M_{x\theta}^{k} - M_{x\theta}^{k-1}}{\Delta x} \quad (\theta = \theta_o) \qquad (50b)$$

$$\bar{R} = -\frac{h^2}{2} \sum_{i=1}^{\bar{L}} \xi_i H_i \sigma_{x\theta}^{i} \quad (x,\theta = o,o;\ell,\theta_o) \qquad (50c)$$

where

$$M_x^{\bar{M}} = \frac{h^2}{4} \sum_{i=1}^{\bar{L}} \xi_i H_i \sigma_{xx(i)}^{\bar{M}}$$

$$M_\theta^{\bar{N}} = \frac{h^2}{4} \sum_{i=1}^{\bar{L}} \xi_i H_i \sigma_{\theta\theta(i)}^{\bar{N}}$$

$$M_{x\theta}^{k} = -\frac{h^2}{4} \sum_{i=1}^{\bar{L}} \xi_i H_i \sigma_{x\theta(i)}^{k}$$

$$\Delta x = \ell/_{\bar{M} - 1}$$

$$\Delta\theta = \theta_o/_{\bar{N} - 1}$$

Similar expressions for V_x and V_θ can be defined for boundaries along $x = o$ and $\theta = o$, respectively.

The tangential reaction forces are given by

$$N_x = \frac{h}{2} \sum_{i=1}^{\bar{L}} H_i \, \sigma_{xx(i)} \tag{51a}$$

$$N_\theta = \frac{h}{2} \sum_{i=1}^{\bar{L}} H_i \, \sigma_{\theta\theta(i)} \tag{51b}$$

To estimate the loads on a fastener at a given location the determined reaction forces per unit length near the specified boundary location can be multiplied by the fastener spacing. For the normal reaction forces the sign convention designates positive force in the positive z direction and negative force in the negative z direction. For the tangential reaction forces the sign convention designates positive force in tension and negative force in compression. It should be noted that the accuracy of the solution for these reaction forces is limited by the number of modes and spatial integration points that are allowed by the core of the computer used.

2.8 Approximate Solution for Elastic-Plastic Response of Sandwich Panels

The elastic-plastic option of DEPROP is limited to handling single-layered isotropic panels, so that a thin three-layered isotropic sandwich panel is reduced within the program to an equivalent single-layered panel based on equating corresponding extensional and bending stiffnesses. A sandwich panel with face sheets of the same material described by σ_o, ϵ_o, E and E_t, can be reduced to an equivalent single-layered panel defined by the following quantities in terms of the nomenclature of Figure 4:

$$h_e = \frac{(h_3 + h_2 - h_1)}{(h_3 - h_2 + h_1)} \; [3h_1(h_3 - h_2)]^{1/2} \tag{52a}$$

$$E_e = \frac{E(h_3 - h_2 + h_1)}{h_e} \tag{52b}$$

$$\sigma_o^e = E_e \varepsilon_o \tag{52c}$$

$$E_t^e = \frac{E_t(h_3 - h_2 + h_1)}{h_e} \tag{52d}$$

$$\rho_e = \frac{1}{h_e} \sum_{k=1}^{3} \rho_k (h_k - h_{k-1}) \tag{52e}$$

where

h_e = equivalent thickness

E = elastic modulus of face sheets (equal to σ_o/ε_o)

E_e = equivalent elastic modulus

E_t = strain hardening modulus of face sheets

E_t^e = equivalent strain hardening modulus

ρ_e = equivalent mass density

σ_o^e = equivalent yield stress

2.9 Panel Loading Program Options

Four transient pressure loadings option are incorporated into the DEPROP program to describe the pressure function p (x,θ,t) which is designated as positive in the negative z-direction. The first loading option is an analytical representation of the transient pressure on a flat panel generated from the detonation of a projectile fired into an adjacent fluid medium. The second option provides a method for a more arbitrary pressure loading through spatial and temporal discretization of the pressure field. The third option contains a simple uniform pressure distribution over the panel with a combination of exponential and triangular time decay behind a sharp-edged blast front. The fourth option is also for a uniform pressure loading, but with an arbitrary temporal discretization. These loading options are discussed briefly in the following paragraphs.

2.9.1 Loading Option 1

This option describes a transient pressure loading $p(x,y,t)$ generated from test data obtained on a flat plate subjected to the pressure loading from the detonation of a projectile fired into an adjacent fluid medium. As shown in Figure 6 the trajectory of the projectile is defined by the obliquity angle ϕ and the detonation position is a distance Z from the flat panel. This pressure model is based on the assumptions that the shock wave shape is spherical, shock velocity is constant at 58,800 inch/second and the pressure pulse is triangular with a duration of t_d. If it is assumed that time (sec) initiates when the blast wave reaches the center of the panel, the time of arrival of the blast wave at an arbitrary point (x,y) on the panel is given by

$$t_a = \frac{R - Z}{58800} \qquad (53)$$

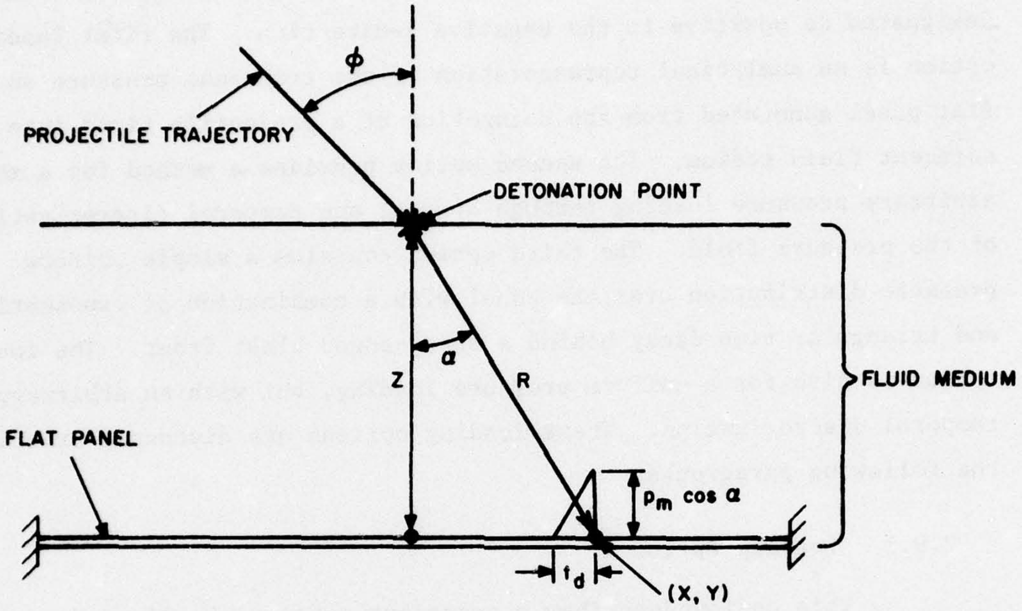


Figure 6. Loading Geometry

where R is the distance from the detonation point given by

$$(x^2 + y^2 + Z^2)^{1/2}$$

The normal pressure p(x,y,t) at this arbitrary point on the panel is described as:

$$p(x,y,t) = 0 \qquad (t < t_a)$$

$$p(x,y,t) = 0 \qquad (t > t_a + t_d) \tag{54}$$

$$p(x,y,t) = p_m \cos \alpha \left(1 + \frac{t_a - t}{t_d}\right) \qquad (t_a \leq t \leq t_a + t_d)$$

where

$$p_m = 484.95 \left(t + \frac{Z}{58800}\right)^{-.29} \qquad \text{(psi)}$$

$$\cos \alpha = Z/R$$

$$t_d = A - B \left(t + \frac{Z}{58800}\right) \qquad \text{(sec)}$$

$$\text{for } \phi = 0^\circ : \; A = 87 \times 10^{-6} \; , \; B = .0686$$

$$= 30^\circ : \; A = 90 \times 10^{-6} \; , \; B = .1127$$

$$= 60^\circ : \; A = 84 \times 10^{-6} \; , \; B = .1275$$

2.9.2 Loading Option 2

A nonuniform load can be applied to either a curved or flat panel by specifying a discrete pressure-time history for an array of selected points covering the surface of the panel. The spatial array of points need not coincide with the integration grid point (determined by $\bar{M}$, $\bar{N}$), but must be a regular grid in the sense that all points remain in rows and columns in the x-θ plane, although the spacing between rows (and columns) need not be constant. The spatial grid should also span the entire portion of the panel analyzed or the program will be forced to linearly extrapolate pressures toward the edges.

The timewise variation is specified at a set of evenly spaced times - the spacing, $\Delta\bar{t}$, is the same for all points. However, the time history of each point does not begin until time corresponding to a unique delay time has been reached. This delay time corresponds to the time of shock arrival and is specified on input for each grid point. It is important that the first point in the array to be engulfed have a delay time equal to zero.

Pressures at intermediate times and interior spatial points are determined by linear interpolation. No attempt has been made to estimate shock arrival at interior points, thus, the shock wave will tend to be smeared unless a great number of grid points are used. For times beyond the last time allowed for in the loading, a pressure equal to the last value specified at that grid point is used.

2.9.3 Loading Option 3

The third load option assumes a uniform distribution over the surface of the panel, with simultaneous engulfment. A single pressure-time history describes the entire loading sequence. The pressure loading is an analytical representation of a combination of triangular and exponential decay, as indicated in Figure 7. The pressures in the three regions indicated in Figure 7 are given in analytical form as follows:

$$p_I(t) = p_1 \left(1 - \frac{t}{t_1}\right) \qquad (t < t')$$

$$p_{II}(t) = p_o \left(1 - \frac{t}{t_o}\right)^n e^{-\frac{at}{t_o}} \qquad (t' \leq t < t_o) \qquad (55)$$

$$p_{III}(t) = 0 \qquad (t \geq t_o)$$

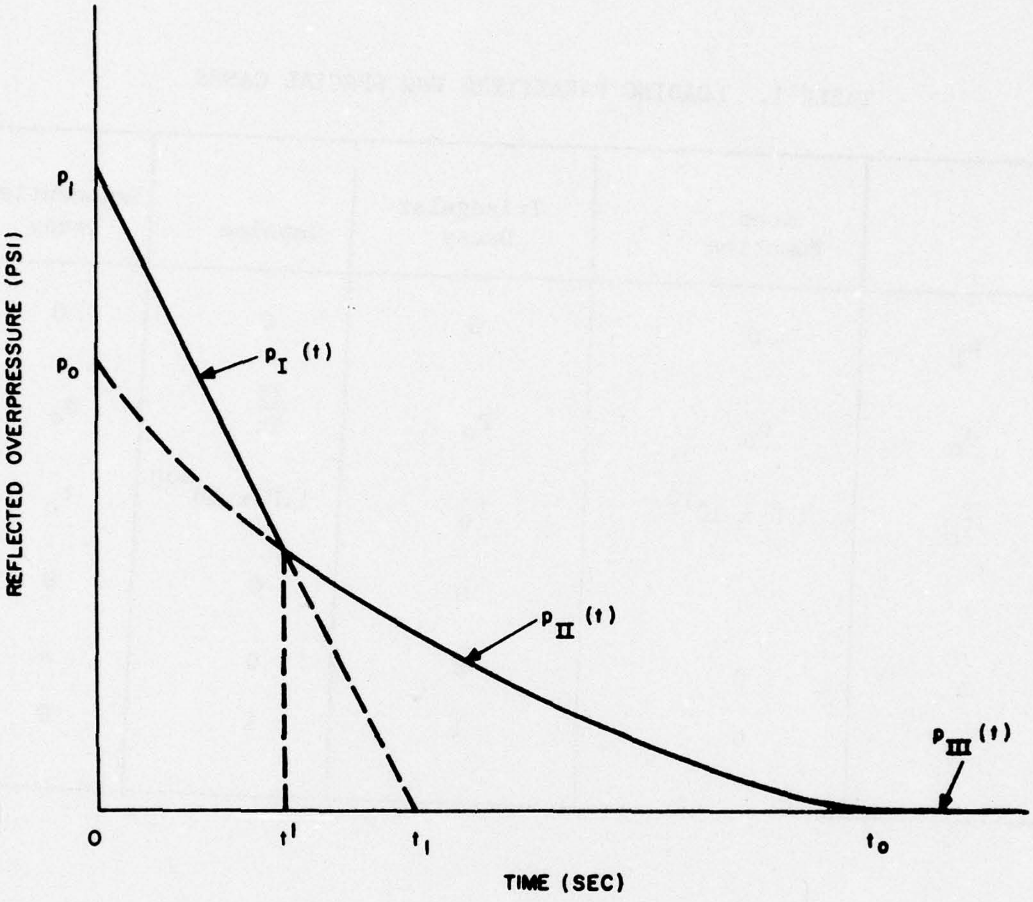


Figure 7. Analytical Pressure Time History

It should be noted that the second function is used for time greater than or equal to t'; hence, by specifying t' = 0 the special loading cases indicated in Table 1 (step, triangular, impulse, exponential) can easily be generated, where I is the impulse and Δt is the integration time interval.

TABLE 1. LOADING PARAMETERS FOR SPECIAL CASES

	Step Function	Triangular Decay	Impulse	Exponential Decay
p_1	0	0	0	0
p_o	p_o	p_o	$\frac{2I}{\Delta t}$	p_o
t_o	1.0×10^{10}	t_o	1.0×10^{-20}	t_o
t'	0	0	0	0
a	0	0	0	a
n	0	1	1	0

2.9.4 Loading Option 4

Like the previous option, loading option 4 is appropriate for uniformly applied loads without consideration of engulfment. With this option, discrete values of pressures are specified at a set of times, beginning at zero. For other times, linear interpolation is used, except after the last time in the table, when a pressure equal to the last value is assumed.

SECTION III

PROGRAM DESCRIPTION AND OPERATION

The DEPROP computer program determines the structural response of cylindrical or flat panels to an applied pressure loading. The dynamic response can be either elastic or elastic-plastic, where the elastic option applies to single and multilayered panels of isotropic or orthotropic material, and the elastic-plastic option applies to single layer panels of isotropic material. Any combination of clamped and simply-supported edge conditions is permitted.

The dynamic pressure loading options provided in the program are in the form of either an analytical function of (x, y, t) or a discrete point-by-point data specification, so that either arbitrary loadings or certain specific loadings are accommodated by the program. Provision is also made in the program to determine the elastic response to a uniformly applied static load, or the static load followed by a dynamic load.

The first two subsections describe the code, including a brief summary of individual routines, flow diagrams, and definitions of the major program variables. The appropriate dimensions of all program variables are also listed in case that the user should want to change program dimensions.

Subsections 3.3 to 3.5 deal with actual program operation - how to input the data, program requirements, and a description of the output, including certain error messages which might be encountered.

A SUPER INDEX listing of all program variables is presented in Appendix A, and a complete program listing can be found in Appendix B.

3.1 Description of the Routines

Table 2 lists the 19 routines and all common blocks which make up DEPROP. The decimal length of each common is also indicated.

Flow diagrams of the major routines are presented in Figures 8 to 12, while brief descriptions of the purpose of all the routines are given below. Also included are lists of the routines which are referenced by other routines and vice-versa.

DEPROP

Main program. Reads preliminary input data and controls program flow.
Calls PINIT, PROP.

BOLT

Sets up W mode shapes for boundary conditions selected.
Called by DSET1.

DERV2

Computes strains, displacements, and accelerations in the main integration loop.
Calls LIST1, LIST2, PRESS, REIT, SIGMA.
Called by PROP.

DSET1

Reads DEPROP input data and calculates constants.
Called by PROP.

DSET2

Calculates constants used in DEPROP.
Calls LEGEND, DTSTEP.
Called by PROP.

DSET3

Calculates additional constants and writes out a description of input data.
Calls BOLT.
Called by PROP.

DTSTEP

Computes an integration time step small enough to avoid numerical instabilities.
Called by DSET2.

TABLE 2. DEPROP ROUTINES AND COMMON BLOCKS

COMMON	FIRST	CNOVA	CLOAD	CBLK1	CBLK2	CBLK3	CBLK4	CBLK5	CBLK6	CBLK7	CBLK8	CBLK9	CBLK10	CBLK11	CBLK12	CBLK13	CBLK14	CHIM	BLANK
Length of Common	1	142	1072	217	4406	12	442	1185	25270	23	891	128	5415	12	22638	9	988	418	14834
Routine																			
DEPROP	X	X	X																
BOLT				X	X														
DERV2		X		X	X	X	X				X		X	X			X		X
DSET1		X		X	X	X	X	X		X	X	X	X	X		X			X
DSET2		X		X	X	X	X	X		X	X	X	X	X		X			X
DSET3		X		X	X	X	X	X		X	X	X	X	X		X			X
DTSTEP		X		X	X											X			
HIM																		X	
LEGEND				X		X													
LIST1		X		X								X	X				X		X
LIST2		X		X						X		X	X				X		X
PINIT		X	X	X							X								X
PRESS		X	X	X							X								X
PROP	X	X		X	X	X	X	X		X	X	X	X	X		X	X		X
REIT				X		X				X			X	X			X		X
RELAXP															X				
SEC																			
SIGMA		X		X		X	X		X	X									X
SOLVE																			

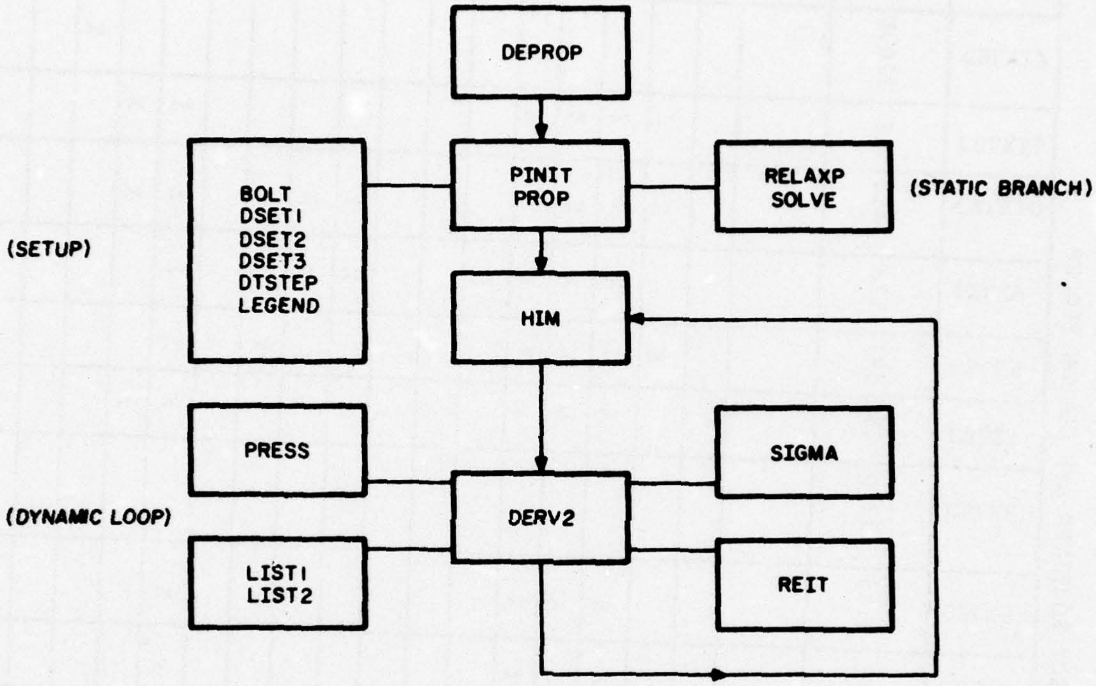


Figure 8. Major Program Flow

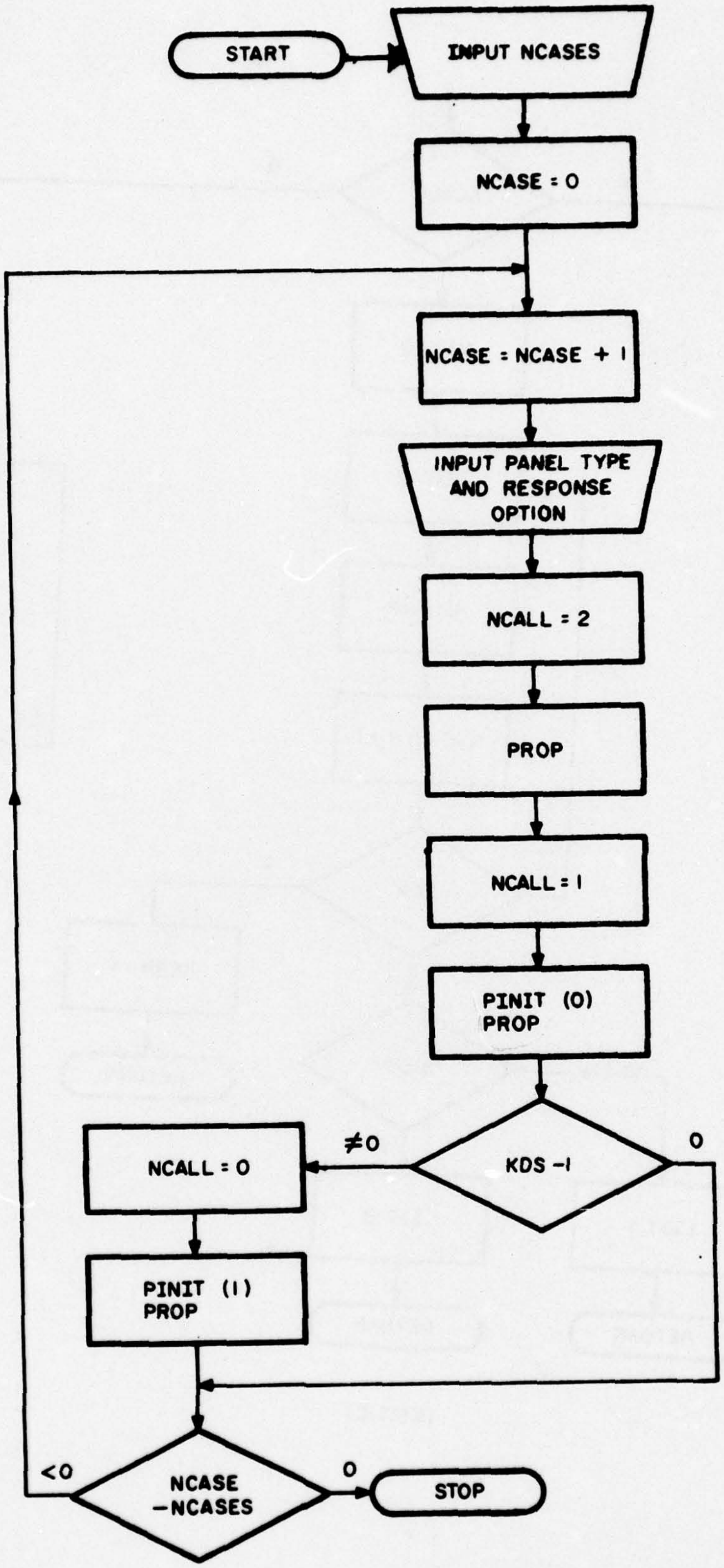


Figure 9. Program DEPROP Flow Diagram

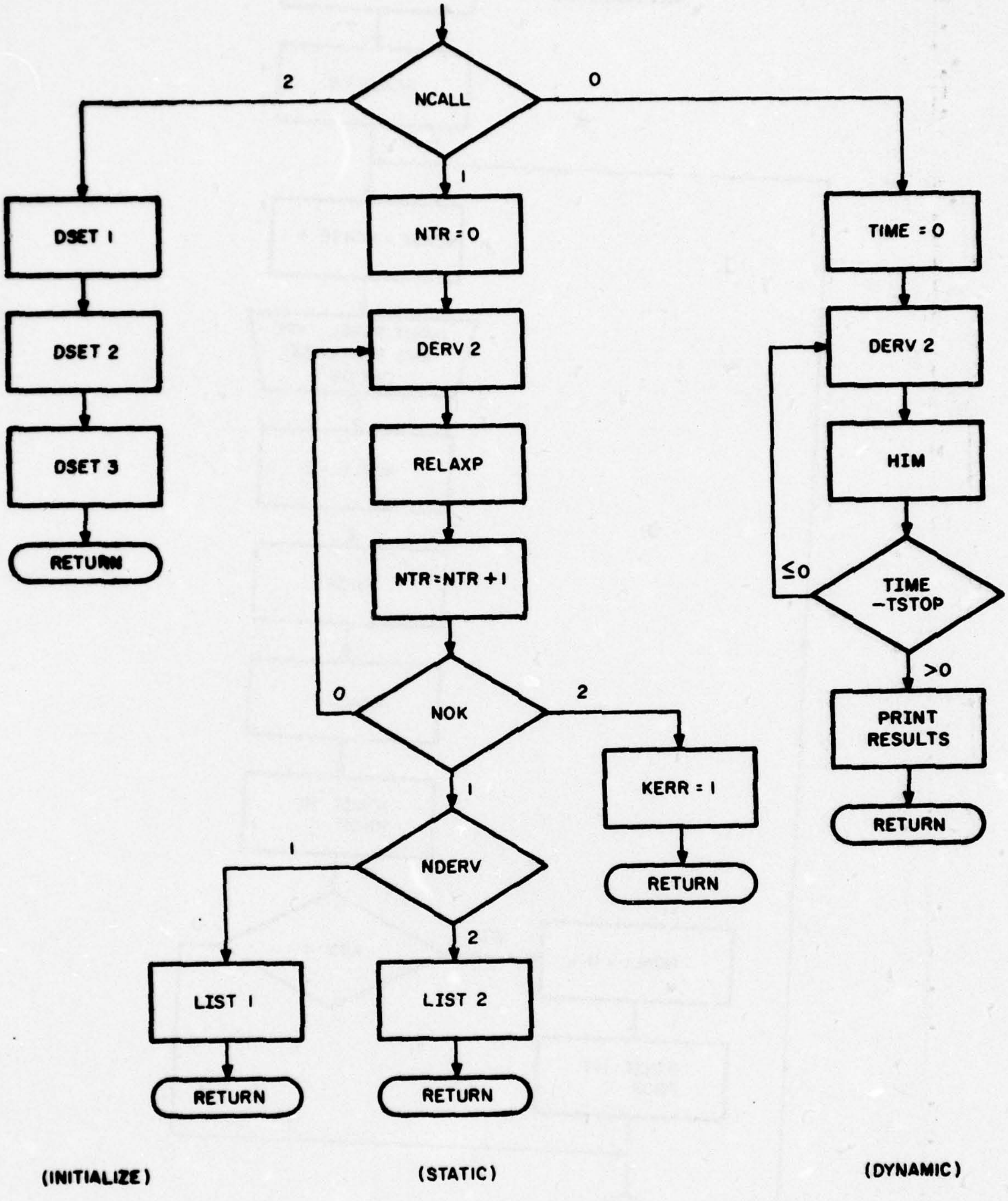


Figure 10. Subroutine PROP Flow Diagram

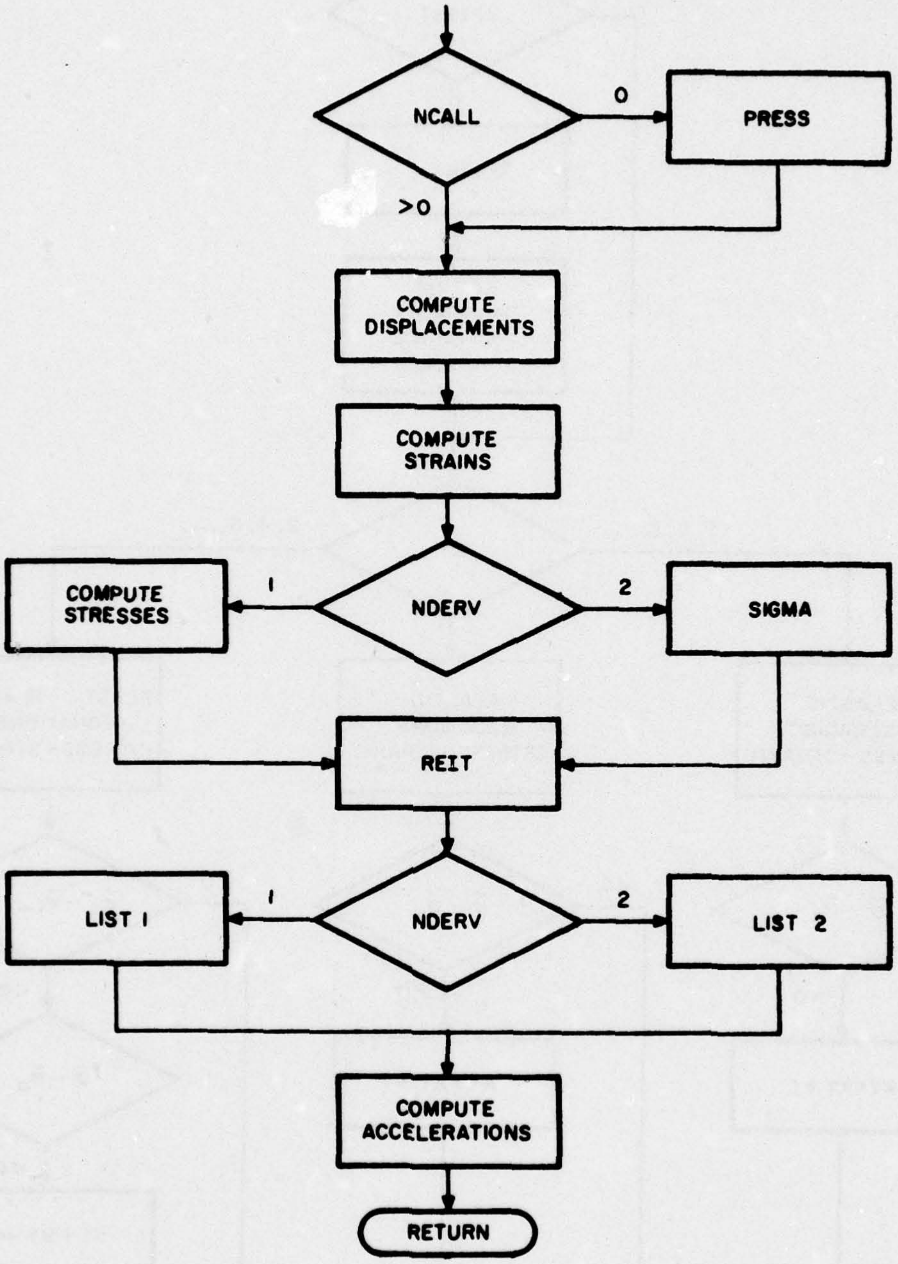


Figure 11. Subroutine DERV2 Flow Diagram

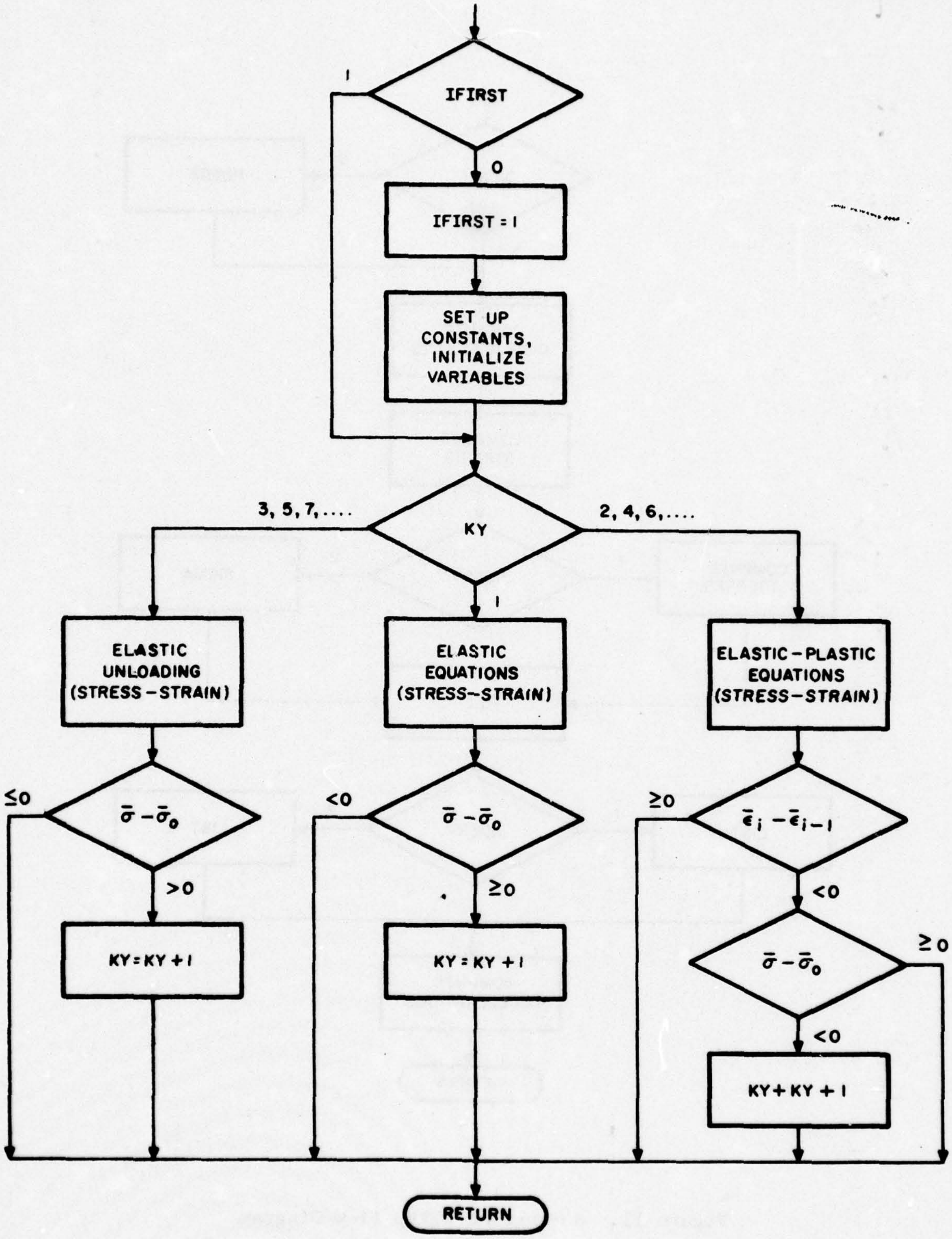

IFIRST
1
0
IFIRST = 1
SET UP CONSTANTS, INITIALIZE VARIABLES
KY
3, 5, 7, ...
2, 4, 6, ...
1
ELASTIC UNLOADING (STRESS – STRAIN)
ELASTIC EQUATIONS (STRESS – STRAIN)
ELASTIC – PLASTIC EQUATIONS (STRESS – STRAIN)
≤0
σ̄ – σ̄₀
>0
KY = KY + 1
<0
σ̄ – σ̄₀
≥0
KY = KY + 1
≥0
ε̄ᵢ – ε̄ᵢ₋₁
<0
σ̄ – σ̄₀
≥0
<0
KY + KY + 1
RETURN

Figure 12. Subroutine SIGMA Flow Diagram

HIM

Numerical timewise integration routine.
Called by PROP.

LEGEND

Sets up constants for Gaussian integration through the thickness for an elastic-plastic solution.
Called by DSET2.

LIST1

Output routine for the elastic-only option.
Called by PROP, DERV2.

LIST2

Output routine for the elastic-plastic option.
Called by PROP, DERV2.

PINIT

Reads in pressure loading time history. Sets up loading functions.
Called by PROP.

PRESS

Calculates pressure loading at a given time.
Called by DERV2.

PROP

Executes the static and dynamic panel solutions.
Calls DERV2, DSET1, DSET2, DSET3, HIM, LIST1, LIST2, RELAXP, SEC.
Called by DEPROP.

REIT

Computes reaction forces at the boundaries and corners.
Called by DERV2.

RELAXP

Solves simultaneous nonlinear equations representing preblast conditions using a relaxation procedure.
Calls SOLVE.
Called by DEPROP.

SEC

Finds elapsed CP time.
Calls system routine SECOND.
Called by PROP.

SIGMA

Computes stresses in the main integration loop for the elastic-plastic option. Is not needed for the elastic-only option.
Called by DERV2.

SOLVE

Solves a set of simultaneous linear algebraic equations.
Called by RELAXP.

3.2 Definition of Major Program Variables

The major program variables are defined in this subsection. These variables are listed alphabetically with a brief description devoted to each one. An asterisk preceding a variable name indicates that the variable is input as run data. The dimension of a variable is given parenthetically after the variable name, where a numerical dimension indicates the fixed amount of storage required for the variable. There is no need to change the dimension of such a variable. However, other variables have variable dimensions. As an example, one of the first dimensioned variables listed is BETR(NBAR). The dimension is a variable, NBAR, which represents the number of spatial integration points used in the beta-direction in the panel. This dimension must be the largest number of points the user intends to employ. In the DEPROP program, this dimension is 23. If additional integration points are required, the dimension of NBAR must be increased, thus increasing the dimensions for all variables with the dimension, NBAR. The current dimensions provided for the variables in the DEPROP routines are given in Table 3.

Almost all of the variables which may require dimension changes as indicated above are contained in the COMMON blocks. There are a few exceptions and, in such cases, the subroutine in which the variable is dimensioned is indicated in the list of variables or in Table 4. If the dimensions are changed, certain additional changes in the program may be required. These changes are also indicated in Table 4.

Many of the variables found in the program result from their use in the larger NOVA-2 code (Reference 1). In most cases, these variables have little or no use in DEPROP and are so indicated.

TABLE 3. DIMENSIONS OF DEPROP VARIABLES

VARIABLE	DIMENSION
LBAR	6
MB	13
MBAR	23
MBAR*NBAR*LBAR[1]	1805
MG	13
MGMB[2]	49
NBAR	23
NGNBT[3]	361
NKP	46
NL	8
NPX	10
NPY	10

1. This constraint is only significant for an elastic-plastic run (NDERV=2). Three possible combinations using maximum dimensions are: (17x17x6), (19x19x5), (21x21x4).

2. The total number of modes selected (MGMB) from the total possible (MB*MG) cannot exceed 49.

3. The total number of spatial integration point allowed (NGNBT) from the total possible (MBAR*NBAR) is 361.

TABLE 4. PROGRAM CHANGES REQUIRED BY DIMENSION CHANGES

When Changing the Dimensions Corresponding to:	Also Change the Fixed-Point Number in the Indicated Statement	
	Subroutine	Location[1]
MGMB*3	HIM	COMMON BLOCK
LBAR	LEGEND	300^{-11}
MGMB*3	RELAXP	20^{+1}

---

[1] The location code is read as follows: s^{+n} refers to the nth line after statement number s.

Major Program Variables for DEPROP Routine

*A	Radius of the cylindrical panel, a, in. Is set equal to 1.0 for flat panel.
*AA	Pressure loading parameter, a, dimensionless (Load Option 3)
ALTT(LMAX)	Change in stress component, $\tilde{\alpha}_{\theta\theta}$, psi
ALXT(LMAX)	Change in stress component, $\tilde{\alpha}_{x\theta}$, psi
ALXX(LMAX)	Change in stress component, $\tilde{\alpha}_{xx}$, psi
*ANN	Pressure loading parameter, n, dimensionless (Load Option 3)
AZ	Constant equal to a/t_o, 1/sec (Load Option 3)
BE1(LMAX)	Change in strain component, $\tilde{\beta}_{xx}$, in/in.
BE2(LMAX)	Change in strain component, $\tilde{\beta}_{\theta\theta}$, in/in.
BE3(LMAX)	Change in strain component, $\tilde{\beta}_{x\theta}$, in/in.
BETR(NBAR)	Integration positions in the beta-direction, rad
BTL(NL)	Constants used in elastic option, $E_\theta^k/(1-\nu_x^k\nu_\theta^k)$, psi
BXL(NL)	Constants used in elastic option, $E_x^k/(1-\nu_x^k\nu_\theta^k)$, psi
CCRIT(NL)	Not used
CC1(MG)	Constant, m, dimensionless
CC2(MB)	Constant, n, dimensionless
CC5(MG)	Constant, m+1, dimensionless
CC6(MB)	Constant, n+1, dimensionless
CINST(3)	Not used
CK(6)	Constants, $1/k_\gamma$, $1/k_\beta$, for the equations of motion, dimensionless
CM11,CM12, CM22,CM33	Stiffness constants C_{ij} used in elastic, multi-layer integration through the thickness, lb/in.

CN10	Constant, $2L^2R$ for elastic option, $2L^2$ for elastic-plastic option, dimensionless
CN11	Constant, $2L^2R$ for elastic option, $L^2/6R^2$ for elastic-plastic option, dimensionless
CN6	Constant for elastic-plastic option, $E/(1-\nu^2)$, psi
CN7	Shear modulus for elastic-plastic option, $E/2(1+\nu)$, psi
CN8	Constant, L^2, dimensionless
CN9	Constant, $L^2/2R$, dimensionless
COSB(MB*NBAR)	Cosine functions of the beta angles, $\cos((n+1)\beta_j)$, dimensionless.
COSG(MG*MBAR)	Cosine functions of the gamma angles, $\cos((m+1)\gamma_i)$, dimensionless
COS2B(MB*NBAR)	Cosine functions of the beta angles, $\cos(n\,\beta_j)$, dimensionless
COS2G(MG*MBAR)	Cosine functions of the gamma angles, $\cos(m\,\gamma_i)$, dimensionless
CRIT(3)	Not used
DC	Not used
DELT	Grid point spacing in β-direction, Δy, in., or $a\Delta\theta$, in-rad
*DELTIM	Integration time interval, sec
DELX	Grid point spacing in γ-direction, Δx, in.
DELX(3*MGMB)	Working array in RELAXP, dimensionless
*DET(NPY,NPY)	Delay time to when spatial point is first engulfed by pressure wave, sec (Load Option 2)
DM11, DM12, DM22, DM33	Stiffness constants D_{ij} used in elastic, multilayer integration through the thickness, lb-in.
DPRT	Running time, in multiples of DPRT1, used to flag next printout, sec
DPRT1	Time interval between printouts, sec

*DTIM	Time interval between specified pressure data, sec (Load Option 2)
DWB(NGNBT)	Values for imperfection-related partial derivative $\overset{o}{W}_{\beta}$, dimensionless
DWG(NGNBT)	Values for imperfection-related partial derivatives $\overset{o}{W}_{\gamma}$, dimensionless
DWO(NGNBT)	Values for imperfection-related displacement $\overset{o}{W}$, dimensionless
DX1(MBAR)	Fractional distance in γ-direction, locating grid point between two pressure-mesh points, dimensionless (Load Option 2)
DY1(NBAR)	Same as DX1, only in β-direction
EC	Not used
EL	Modulus of elasticity for elastic-plastic option, E, psi
*EM(NL)	Modulus of elasticity for each layer for elastic-plastic option, E^k, psi
ENX(2*NBAR-2)	Tangential reaction force per unit length along boundary, N_x, lb/in.
ENT(2*MBAR-2)	Tangential reaction force per unit length along boundary, N_θ, lb/in.
*EP	Strain hardening slope for elastic-plastic option, E_t, psi
EPB(LMAX)	Temporary storage used for either $\bar{\varepsilon}$ or $\bar{\sigma}$
EPBO(LMAX)	Equivalent stress, squared, when response is still elastic for the elastic-plastic option, $\bar{\sigma}^2$, lb^2/in^4.
EPO	Equivalent yield strain corresponding to SIGO for elastic-plastic option, $\bar{\varepsilon}_o$, in/in.
*EPSIF	Ultimate (fracture) strain for elastic-plastic option, ε_f, in/in; not used
ERR(3*MGMB)	Allowable error in displacement coefficients in the static solution

*ET(NL)	Modulus of elasticity in the theta-direction for elastic option, E_θ^k, psi
ETT	Temporary value of strain, $\varepsilon_{\theta\theta}^m$, in/in.
ETT1(LMAX)	Strain component at the time of last yielding, $\varepsilon_{\theta\theta}$, in/in.
*EX(NL)	Modulus of elasticity in x-direction for elastic option, E_x^k, psi
EXT	Temporary value of strain, $\varepsilon_{x\theta}^m$, in/in.
EXT1(LMAX)	Strain component at the time of last yielding, $\varepsilon_{x\theta}$, in/in.
EXX	Temporary value of strain, ε_{xx}^m, in/in.
EXX1(LMAX)	Strain component at the time of last yielding, ε_{xx}, in/in.
*FG(MB,MG)	Modal displacement coefficients for the initial imperfections, in.
FM11, FM12 FM22, FM33	Stiffness constants F_{ij} used in elastic, multilayer integration through the thickness, lb
FP1(MG*MBAR)	Displacement function, $\phi_m^w(x)$, dimensionless
FP2(MG*MBAR)	$\frac{\partial}{\partial\gamma}\ \phi_m^w(x)$, dimensionless
FP3(MG*MBAR)	$\frac{\partial^2}{\partial\gamma^2}\ \phi_m^w(x)$, dimensionless
FP4(MG,2)	$\frac{\partial^3\phi_m^w}{\partial\gamma^3}$ at $\gamma = 0, \pi$, dimensionless
FP5(MB*NBAR)	Displacement function, $\phi_n^w(\theta)$, dimensionless
FP6(MB*NBAR)	$\frac{\partial\ \phi_n^w(\theta)}{\partial\beta}$, dimensionless
FP7(MB*NBAR)	$\frac{\partial^2\phi_n^w(\theta)}{\partial\beta^2}$, dimensionless

FP8(MB,2)	$\frac{\partial^3 \phi^w_n(\theta)}{\partial \beta^3}$ at $\beta = 0, \pi$, dimensionless
GAM(MBAR)	Integration positions in the γ-direction, rad
GAMMA(41)	Not used
GC	Not used
GX(LBAR)	Zeroes of the Legendre polynomial for the elastic-plastic Gaussian integration through the thickness, ξ_i, dimensionless
*GXT(NL)	Shear modulus, $G_{x\theta}$, psi
H	Thickness of cross section for elastic-plastic option, in.
HBAR	Distance from the inner panel surface to the coordinate surface, $\bar{H}$, in.
HGO(LBAR)	Weighting factors for the elastic-plastic Gaussian integration through the thickness, H_i, dimensionless
*HM(NL)	Distance from the inner panel surface to the outer surface of layer, h, in.
ICOMP	Not used
ICOUNT	Counter, initially set at 3777700000000000000B, and incremented for each integration step in program
IFIRST	Code designating first pass through subroutine SIGMA, dimensionless
INOUT	Not used
INZ(2)	Code designating the appropriate layer number corresponding to the two panel surfaces, dimensionless
IP(3*MGMB)	Working array in RELAXP, dimensionless
IXI(MBAR)	Integer locating grid points in γ-direction relative to pressure-mesh (Load Option 2)
JFIRST	Code which indicates if the panel has yielded for the elastic-plastic option
JL	Lower index on timewise interpolation table (Load Option 4)

JLT(NPY,NPX)	Lower index on timewise interpolation table (Load Option 2)
JYJ(NBAR)	Integer locating grid points in β-direction relative to pressure-mesh (Load Option 2)
KALT	Not used
KB	Not used
KC	Not used
KDAM	Not used
*KDS	Response option code
KERR	Dynamic response error code - 0, no error; 1, error
KOK	Not used
*KPG(NKP)	Mesh point number (γ), when paired with KPB, calling for printout
*KPB(NKP)	Mesh point number (β), when paired with KPG, calling for printout
KSUMA(NGNBT)	Number of z points which have not yielded at each spatial station; used only in elastic-plastic option
*KTYPE	Code designating panel type 1, single-layer metal 2, honeycomb panel (3 layers) 5, multilayer panel (elastic response only)
KY(LMAX)	Code in elastic-plastic response, indicating number of times an integration point has yielded, unloaded, etc.
KZ	Code deciding whether the output routine should print
*LBAR	Number of integration points through the thickness; is assumed to be one for elastic option
LMAX	Maximum number of integration points being used; equal to MBAR*NBAR*LBAR
*MB	Number of beta modes to be incorporated into the solution

*MBAR	Number of beta integration points to be used; for a symmetric boundary condition, only approximate half as many points are required
*MG	Number of gamma modes to be incorporated into the solution
*MGM(MG)	Gamma mode numbers
MGMB	Constant, equal to the total number of modal combinations used, MG*MB-NNOUT
MGMB2	Constant, 2*MGMB
*MOUT(MG*MB)	Gamma modes <u>not</u> to be included, in combination with the corresponding NOUT mode
MUSE(MB,MG)	Code designating which modal combinations are to be used
NB	Beta-point number corresponding to centerline of panel
*NBAR	Number of gamma integration points to be used; for a symmetric boundary condition, only approximately half as many points are required as otherwise.
*NBN(MB)	Beta mode numbers
*NBND	Boundary condition code
NBT	Total number of beta points monitored
NCALL	Code describing program phase: 0, find dynamic response 1, find static solution 2, read data, set up constants
NCASE	Case number currently being run
*NCASES	Number of cases to be run
NCHPT	Not used
*NDBUG	Output debugging control: 0, no debug output (normal option) 1, most debug output 2, all debug output.
*NDERV	Response code: 1-elastic (multilayer, orthotropic, 2-elastic-plastic (single layer, isotropic)

NELP	Response code for the elastic-plastic option: 1-keep solution elastic, 2-allow solution to go elastic-plastic
NG	Gamma-point number corresponding to center line of panel
NGNB	The spatial integration point number corresponding to the center of the panel
NGNBT	Total number of spatial integration points used
NGT	Total number of gamma points monitored
*NKP	Number of spatial points for which printout of strains, stresses, reactive forces, displacements and pressure is required
*NL	Number of layers.
*NLOAD	Pressure load option code: 1, nonuniform, functions 2, nonuniform, discrete 3, uniform, functions 4, uniform, discrete
NLZ(2*NL)	Layer number corresponding to each layer's upper and lower surfaces
NMASS	Not used
*NNOUT	Number of modal combinations (<MG*MB) to be eliminated from the solution
*NOUT(MG*MB)	Beta modes <u>not</u> to be included, in combination with the corresponding MOUT mode
*NPLT	Panel type code: 0-flat, 1-curved
*NPX	Number of mesh points in γ-directions for which pressure data is provided (Load Option 2)
*NPY	Number of mesh points in β-direction for which pressure data is provided (Load Option 2)
NREG	Not used
*NSYMB	Symmetry code in the beta-direction: 0-symmetric, 1-not symmetric

*NSYMG	Same as NSYMB, except in the gamma-direction
NTECO	Not used
*NTIME	Number of times for which pressure data is provided. (Load Options 2 and 4)
NTRIAL	Not used
NU	Code indicating whether loading is spatially uniform or not: 0-not uniform, 1-uniform
NUSE(NBAR,MBAR)	Use code for the spatial integration stations: 0-not used, 1-not used for printout only, 2-used for integration only, 3-both
NY2	Constant, equal to 3*MGMB
NZP	Not used
OTTO	Constant equal to $1/t_0$, 1/sec (Load Option 3)
OTT1	Constant equal to $1/t_1$, 1/sec (Load Option 3)
P(NGNBT)	Pressure at each spatial point, psi
PB(40)	Not used
PDAM	Not used
*PHI	Angle projectile trajectory makes with the normal to the panel (z-axis), ϕ, degrees (Load Option 1)
PI	Constant, equal to π
PIMA(MBAR)	Constants associated with the equation of motion and Simpson's Rule; Gamma-direction, $in^2/lb\text{-}sec^2$
PINA(NBAR)	Same as PIMA, only in the beta-direction
PPP	Calculated pressure on panel (uniform distributions only), psi
*PP1	Pressure P_1, psi (Load Option 3)
*PPO	Pressure P_0, psi (Load Option 3)
*PRINT	Output frequency - integration steps per printout

PRES(3*MGMB)	Working array in RELAXP, dimensionless
*PRT(NTIME,NPY,NPX)	Pressure specified on panel vs time, psi (Load Option 2)
PRTT(NPY,NPX)	Temporary storage for pressure on panel after interpolation on time, psi (Load Option 2)
*PT(20)	Table of uniform pressures specified on panel, psi (Load Option 4)
PX(3*MGMB)	Working array in RELAXP, dimensionless
Q1	Constant A (Load Option 1)
Q2	Constant B (Load Option 1)
RA(NBAR,MBAR)	Range from detonation point, R, in.
RFR	Not used
RHO	Density of panel, lb-sec^2/in^4
*RHOM(NL)	Density of layer, lb-sec^2/in^4
RR(4)	Reaction force at corners of panel
RRES(3*MGMB)	Working array in RELAXP, dimensionless
RTRIAL(5)	Not used
SAC(NL)	Compressive yield stresses for metal material, compressive ultimate stress for plastic material, psi; not used
SAT(NL)	Tensile yield stress for metal materials, tensile ultimate stress for plastic material, psi; not used
*SIGO	Yield stress for elastic-plastic option, psi
SIGO2	Constant, equal to SIGO squared, lb^2/in^4.
SIGTT1(LMAX)	Stress component at time of last yielding, $\sigma_{\theta\theta}$, psi
SIGX(3*MGMB)	Working array in RELAXP, dimensionless
SIGXT1(LMAX)	Stress component at time of last yielding, $\sigma_{x\theta}$, psi

SIGXX1(LMAX)	Stress component at time of last yielding, σ_{xx}, psi
SINB(MB*NBAR)	Sines of beta functions, sin($(n+1)\beta_j$)
SING(MG*MBAR)	Sines of gamma functions, sin ($(m+1)\gamma_i$)
SIN2B(MB*NBAR)	Sines of beta functions, sin($(n)\beta_j$)
SIN2G(MG*MBAR)	Sines of gamma functions, sin($(m)\gamma_i$)
S1A(NGNBT)	Stress component, σ^m_{xx}, psi
S2A(NGNBT)	Stress component, $\sigma^m_{\theta\theta}$, psi
S3A(NGNBT)	Stress component, $\sigma^m_{x\theta}$, psi
S4A(NGNBT)	Stress component, σ^b_{xx}, psi
S5A(NGNBT)	Stress component, $\sigma^b_{\theta\theta}$, psi
S6A(NGNBT)	Stress component, $\sigma^b_{x\theta}$, psi
SMAX	Not used
STT(LMAX)	Stress component, $\sigma_{\theta\theta}$, psi
SXT(LMAX)	Stress component, $\sigma_{x\theta}$, psi
SXX(LMAX)	Stress component, σ_{xx}, psi
*THETAO	Total angle subtended by cylindrical panel, θ_0, deg, or width of flat panel, b, in.
*THNU(NL)	Poisson's ratio in the theta-direction, ν_θ, dimensionless
*TITLE(20)	Descriptive title of case
TMAX	Not used
*TNU	Poisson's ratio for elastic-plastic option
*TPRIME	Time t' (Load Option 3), sec
*TSTOP	Integration stop time, sec
*TT(20)	Time table (Load Option 4), sec

TTNU(LMAX)	Value of ν_s, dimensionless
U(NGNBT)	Value of U, dimensionless
UB(NGNBT)	Value of U_β, dimensionless
UG(NGNBT)	Value of U_γ, dimensionless
UU(MB,MG)	Displacement coefficient, U_{mn}, dimensionless
U1(MB,MG)	Displacement coefficients, U_{mn}, representing the static conditions, dimensionless
V(NGNBT)	Value of V, dimensionless
VB(NGNBT)	Value of V_β, dimensionless
VG(NGNBT)	Value of V_γ, dimensionless
VRX(2*NBAR-2)	Normal reactive force per unit length along boundary, V_x, lb/in.
VRT(2*MBAR-2)	Normal reaction force per unit length along boundary, V_x, lb/in.
VS	Shock velocity, equal to $5.88\text{x}10^4$ in/sec (Load Option 1)
VV(MB,MG)	Displacement coefficients, V_{mn}, dimensionless
VXO(3*MGMB)	Initial velocity coefficients
V1(MB,MG)	Displacement coefficients, V_{mn}, representing the static conditions, dimensionless
W(NGNBT)	Value of W, dimensionless
WB(NGNBT)	Value of W_β, dimensionless
WBB(NGNBT)	Value of $W_{\beta\beta}$, dimensionless
WBBB(2*MBAR-2)	Value of $W_{\beta\beta\beta}$, dimensionless
WG(NGNBT)	Value of W_γ, dimensionless
WGB(NGNBT)	Value of $W_{\gamma\beta}$, dimensionless
WGBB(2*NBAR-2)	Value of $W_{\gamma\beta\beta}$, dimensionless
WGG(NGNBT)	Value of $W_{\gamma\gamma}$, dimensionless
WGGB(2*MBAR-2)	Value of $W_{\gamma\gamma\beta}$, dimensionless
WGGG(2*NBAR-2)	Value of $W_{\gamma\gamma\gamma}$, dimensionless

WW(MB,MG)	Displacement coefficients, W_{mn}, dimensionless
W1(MB,MG)	Displacement coefficients, W_{mn}, representing the static conditions, dimensionless
XB(NBAR)	Integration positions in the beta-direction inches for flat panel, degrees for curved panel
XG(MBAR)	Integration positions in the gamma-direction, inches
XJ	Constant, J, equal to $180/\theta_0$ (dimensionless) for curved panel and π/b (inches) for flat panel
XJ2	Constant, J^2
XJ3	Constant, J/L
XJ4	Constant, 2J
XJ5	Constant, 2J/L
XKTT	Temporary value of strain, $\varepsilon^b_{\theta\theta}$, in/in.
XKXT	Temporary value of strain, $\varepsilon^b_{x\theta}$, in/in.
XKKK	Temporary value of strain, ε^b_{xx}, in/in.
XL	Constant, ℓ/π, for flat panel (inches), $\ell/\pi a$ for curved panel (dimensionless)
*XLP	Length of panel, ℓ, inches
XLP1	Constant, $2L^2R$
XLP2	Constant, 2LR
XL1	Constant, 1/L
XL2	Constant, L^2
XL3	Constant, 2/L
XL4	Constant, $2L^2$
XL5	Constant, $2L^2R$
XL7	Constant, $1/L^2$

*XP(NPX)	X-position of pressure-mesh (Load Option 2), in.
XRES(3*MGMB)	Working array in RELAXP, dimensionless
XX(3*MBMG)	Array composed of UU, VV, and WW, dimensionless
*XXNU(NL)	Poisson's ratio in the x-direction, ν_x, dimensionless
XX1(3*MGMB)	Working array in RELAXP, dimensionless
X1A(NGNBT)	Strain component, ε^m_{xx}, in/in.
X2A(NGNBT)	Strain component, $\varepsilon^m_{\theta\theta}$, in/in.
X3A(NGNBT)	Strain component, $\varepsilon^m_{x\theta}$, in/in.
X4A(NGNBT)	Strain component, ε^b_{xx}, in/in.
X5A(NGNBT)	Strain component, $\varepsilon^b_{\theta\theta}$, in/in.
X6A(NGNBT)	Strain component, $\varepsilon^b_{x\theta}$, in/in.
*YP(NPX)	Y-position of pressure-mesh (Load Option 2), in. or deg
YY(3*MGMB)	Array composed of acceleration coefficients, $\ddot{U}_{mn}$, $\ddot{V}_{mn}$, $\ddot{W}_{mn}$, 1/sec^2
ZA(2)	ZB normalized with a, ZB/a, inches for flat plate, dimensionless for a curved panel
ZB(2)	Not used
ZC(2*NL)	Not used
*ZEE	Distance from panel to detonation, Z, in. (Load Option 1)
ZF(LBAR)	ZH normalized with a, ZH/a, inches for a flat plate, dimensionless for a curved panel
ZG(LBAR)	Gaussian station squared, ξ_i^2, dimensionless

ZH(LBAR)	z coordinates corresponding to the Gaussian integration points through the thickness for the elastic-plastic option, in.
ZZ1(9)	Not used

3.3 Program Operation

The DEPROP program is written in FORTRAN IV and consists of 19 user supplied routines on approximately 2700 cards. The code was developed on the Control Data Corporation (CDC) 6600 computer under the SCOPE 3.4.3 operating system.

In order to minimize the amount of central memory core required to execute the program, the user should eliminate at least one of two options prior to loading. This choice of options is either the elastic static solution capability, where subroutines RELAXP and SOLVE are required, or the elastic-plastic option where subroutines LIST2 and SIGMA are required. These options are outlined in Tables 5 and 6, and the corresponding program core requirements are given. Elimination of the unnecessary subroutines can be accomplished by removing them from the deck (or file) completely, replacing them with dummy routines, or using an SLOAD instruction to selectively load the required routines. The use of blank common enables the program to load and execute at the same core level. Input and output are equated with logical files TAPE5 and TAPE6, respectively, and there are no additional tape or disk file requirements for operating the code.

The FTN compiler has been used to compile the code under "OPT=1" and "R=2" options. Compilation requires approximately 50000_8 cells and 20 seconds CP time.

Computation times will vary considerably, depending on the panel, the complexity of the model, whether or not the solution goes inelastic, and the response time requested. A very rough approximation for an inelastic response is 5×10^{-4} CP seconds per mode, per integration grid point, per time step of response.

TABLE 5. CORE REQUIREMENTS FOR MAJOR PROGRAM OPTIONS

Program Response Option	Input Parameters		Subroutines Eliminated	Core Required to Load and Execute*
	KDS	NDERV		
Elastic (Dynamic)	2	1	RELAXP, SOLVE, LIST2, SIGMA	125 K_8
Elastic (Static)	1 or 3	1	LIST2, SIGMA	200 K_8
Elastic-Plastic (Dynamic)	2	2	RELAXP, SOLVE	210 K_8
Static, followed by Elastic-Plastic (Dynamic)	3	2	None	262 K_8

*Code compiled under FTN option 1

TABLE 6. PANEL RESPONSE OPTIONS

Panel Type (KTYPE)	Response Options (NDERV)
1	1,2
3	1,2*
5	1

*The program forms an equivalent single layer for KTYPE = 3, NDERV = 2

3.4 Program Input Data

Specific instructions are provided in this section to enable the user to provide the necessary card input for the DEPROP program. Preceding these instructions are several paragraphs containing general remarks and amplification of some of the specific instructions.

The input data are specified in groups, where each group begins on a separate card. More than one card may be required for a group, however. The variable type and format corresponding to each data group is given in parentheses in the input instruction and is always in fields of 12. For convenience, floating point numbers can be left justified the field as long as the exponent is right justified. Also, zero values can be replaced by a blank field. Columns 73 through 80 are not used for data and can be used for card identification or other purposes.

All input parameters, where appropriate, should be compared with the maximum dimensions provided for in the program, as delineated in Table 3. This is very important since the program does not attempt to check the input for such violations.

Group 1 provides for the execution of several jobs (or cases) in the same run. All subsequent data groups (2 to 23) must be repeated for each case.

The panel type, response option, and debug options are specified in Group 3. It is important to check Table 5 to insure the correct subroutines are included to the response option selected. It is suggested that the first debug option (NDBUG=0) be selected.

Group 4 contains the number of modes to be used in the solution and the number of integration points to be used. The accuracy of the solution is based on the degree of convergence of stress and strain quantities. These quantities converge less rapidly than the radial displacement. Also, cases involving a clamped edge condition will converge less rapidly than simply-supported cases. Since both computer time and accuracy increase with more modes and points, a trade-off usually becomes necessary. It has been found that about 25 modes give an acceptable general solution for most panels, but more modes are required for better accuracy in determining edge strain and reaction force quantities for clamped panels.

The actual mode numbers are specified in Groups 5 and 6. The maximum value that the mode numbers can assume in the program is 19. When symmetry is taken in either direction (Group 7), or if the pressure loading is symmetrically oriented, only the odd numbered modes (1, 3, 5, ...) are required in that direction.

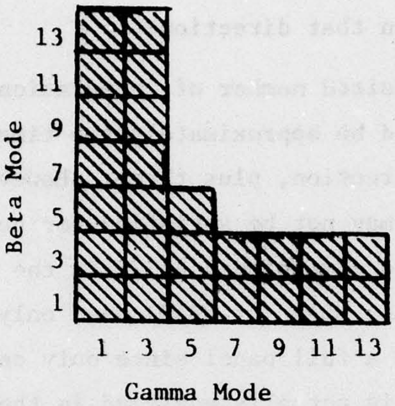
Spatially, the desired number of integration points (MBAR and NBAR) for a full panel should be approximately two times the maximum mode number used in that direction, plus three. However, when NBN or MGM is large, this condition may not be satisfied for nonsymmetrical panels, since MBAR and NBAR are dimensioned at 23 in the program (see Table 3). For symmetric solutions, MBAR (or NBAR) need only be approximately one-half the value for a full panel since only one-half (or one quarter) of the panel is actually analyzed in the solution. For a nonsymmetric condition, MBAR (or NBAR) must be an odd number. For an elastic-plastic solution, a minimum of four integration points through the thickness is recommended, and a maximum of six is provided in the program.

In Group 8, the user is given the option of a purely elastic solution, or an elastic-plastic solution. The elastic-plastic option will tend to be slower and require more computer memory. It should be noted that honeycomb panels are reduced to an equivalent single-layered panel for elastic-plastic response. Again, Tables 5 and 6 should be consulted to insure the program is compatible with the response option selected.

Groups 9 and 10 provide a mechanism for selecting a maximum of 49 modal combinations from a 13 by 13 combination array (MG=MB=13). Thus, the more significant modal combinations for an optimal solution with respect to accuracy and computer time can be selected and the other combinations eliminated. A general rule of thumb is to eliminate the higher frequency modes which are usually associated with modal

combinations having the larger MG+MB values. An example of this would be the selection of MG=MB=7 for a symmetric problem, but eliminating 24 combinations as indicated in Table 7.

TABLE 7. EXAMPLE OF MODAL SELECTION



The relative importance of each modal combination can be evaluated by examining the response output and comparing the magnitudes of the displacement coefficients.

Groups 11 and 12 are responsible for selecting the points in the integration grid for which printout of strains, stresses, displacements, reactive forces (or boundaries), and pressures is required. Strains and stresses are computed at the inner and outer surfaces of the panel. Each point in the grid is designated by a pair of integers, the first integer referring to the gamma-position, the second to the beta-position. Actual positions are found from

$$x = \frac{\ell}{2}\,\frac{(I-1)}{(\bar{M}-1)} \qquad I = 1,\ldots,\bar{M}$$

(symmetric in x-direction)

$$x = \ell\,\frac{(I-1)}{\bar{M}-1} \qquad I = 1,\ldots,\bar{M}$$

(full in x-direction)

and similar expressions for y (or θ). For example, the corner point in a symmetric panel would be numbered (1,1); the center, (MBAR,NBAR).

Group 20 contains the modal components, δ_{mn}, for the initial radial imperfections. The analyst must compute the δ_{mn}'s from measured data using the integration technique applied to Fourier series coefficients. Generally, such data will not be available, and zero values should be specified for the δ_{mn}'s. The capability of considering initial imperfections also enables the analyst to determine the sensitivity of panel response to initial imperfections.

Group 21 provides the integration time increment, the response stop time, and the printout interval. If the user specifies a zero time increment, the program computes an appropriate Δt which, in most cases, will give a stable solution. Because it is approximate, the analyst may want to make comparable runs using different Δt's. In general, an elastic solution which is numerically stable will be accurate. Hence, the optimum Δt is the largest which remains stable. For an elastic-plastic solution, however, the accuracy of the solution may deteriorate slightly as the point at which the solution diverges is approached. Once a time increment is selected, it should be valid for moderate changes in response level.

Although the stop time can vary a great deal, the total number of integration steps required to capture peak response will be roughly between 500 to 1500. One exception to this may be a curved panel experiencing snap-through buckling, in which case considerably larger response times may be required. A printout frequency of once every 20 steps is usually adequate for monitoring the response time history.

Groups 22 to 33 provide for the appropriate pressure load on the panel. The user should refer to Figure 6 or 7 for a definition of certain input parameters.

Group 1: (I12) NCASES

Number of cases to be run. (NCASES)

Group 2: (20A4) TITLE

Identifying title per run, date, etc. Free field. (TITLE)

Group 3: (3I12) KTYPE, KDS, NDBUG

Code designating panel type (KTYPE)
1, Single-layer panel
3, Honeycomb panel (3 layers)
5, Multilayer panel (elastic response only)

Response option code (KDS)
1, static only
2, dynamic only
3, static, followed by dynamic

Debug option (NDBUG)
0, no debug output
1, most debug output
2, all debug output

Group 4: (5I12) MG, MB, MBAR, NBAR, LBAR

Number of gamma modes to be used (MG)

Number of beta modes to be used (MB)

Number of gamma integration points actually used over the portion of the panel analyzed. Must be an odd number for full panel (see Group 7). (MBAR)

Number of beta integration points actually used over the portion of the panel analyzed. Must be an odd number for full panel (see Group 7). (NBAR)

Number of z integration points used through the thickness. (LBAR)
[Not needed for NDERV=1 (see Group 8)]

Group 5: (6I12) (MGM(I), I=1, MG)

Gamma mode numbers, m.

Group 6: (6I12) (NBN(I), I=1, MB)

Beta mode numbers, n.

Group 7: (2I12) NSYMG, NSYMB

Symmetry code in gamma direction (NSYMG):
0, symmetry assumed $(0 \leq \gamma \leq \pi/2)$
1, no symmetry $(0 \leq \gamma \leq \pi)$

Symmetry code in beta direction (NSYMB):
0, symmetry assumed $(0 \leq \beta \leq \pi/2)$
1, no symmetry $(0 \leq \beta \leq \pi)$

Group 8: (3I12) NPLT, NBND, NDERV

Panel type (NPLT):
0, flat panel
1, cylindrical panel

Boundary condition code (NBND).

	γ-direction	β-direction
1,	clamped-clamped	clamped-clamped
2,	simple-simple;	simple-simple
3,	clamped-clamped;	simple-simple
4,	simple-simple;	clamped-clamped
5,	clamped-simple;	clamped-clamped
6,	clamped-clamped;	clamped-simple
7,	clamped-simple;	simple-simple
8,	simple-simple;	clamped-simple
9,	clamped-simple;	clamped-simple

Note: Whenever a clamped-simple condition is selected, the full panel is analyzed in that direction, and NSYMG, NSYMB, MBAR and NBAR should reflect this.

Response option (NDERV):
1, elastic only
2, elastic-plastic

Group 9: (I12) NNOUT

Number of modal combinations to be <u>eliminated</u> from solution (NNOUT).
(0 $\leq$ NNOUT < MG*MB)

<u>If NNOUT=0, skip to Group 11.</u>

Group 10: (2I12) MOUT(I), NOUT(I)

Gamma mode. (MOUT(I))
Beta mode. (NOUT(I))

Repeat Group 10 for I=1, NNOUT. The cards in Group 10 may be arranged in any order.

Group 11: (I12) NKP

Number of spatial points at which printout of stresses, strains, displacements, reactive forces and pressures are requested. If NKP=0, all of the above information will be suppressed.
(NKP)

If NKP=0, skip to Group 13.

Group 12: (2I12) KPG(I), KPB(I)

Integration point in gamma-direction at which printout is requested. Points are ordered 1-MBAR, beginning at $\gamma=0$, and evenly spaced from there. (KPG(I))

Integration point in beta-direction at which printout is requested. Points are ordered 1-NBAR, beginning at $\beta=0$, and evenly spaced from there. (KPB(I))

Note: These two indices are taken as pairs where each pair designates a particular spatial point. The pairs may be specified in any order.

Repeat Group 12 for I=1, NKP.

Group 13: (I12) NL

Number of layers. (NL)
(NL must be 1 for KTYPE=1, and 3 for KTYPE=3)

Group 14: (3F12.1) XLP, THETAO, A

Full length of panel, ℓ, in. (XLP)

Full width of flat panel, b (short direction), in. (NPLT=0)

or

Full subtended angle of cylindrical panel, θ_0, deg. (NPLT=1)

(THETAO)

Radius of cylindrical panel, in. (A)
(Not needed for NPLT=0)

If NDERV=2, skip to Group 18.

Group 15: (2F12.1) HM(I), RHOM(I)

Distance (h) from the inner panel surface to the outer surface of layer I, in. (HM(I))

Mass density of layer I, lb-sec^2/in^4. (RHOM(I))

Group 16: (5F12.1) EX(I), ET(I), XXNU(I), THNU(I), GXT(I)

Modulus of elasticity in the x-direction, psi. (EX(I))

Modulus of elasticity in the theta-direction, psi. (ET(I))

Poisson's ratio in the x-direction. (XXNU(I))

Poisson's ratio in the theta-direction. (THNU(I))

Shear modulus, psi. (GXT(I))

Group 17: (2F12.1) SAT(I), SAC(I)

Tensile yield stress for metal panels; tensile ultimate stress for plastic panels, psi. (SAT(I))

Absolute value of compressive yield stress for metal panels; absolute value of compressive ultimate stress for plastic panels, psi. (SAC(I))

Repeat Groups 15-17 for I=1, NL.

Skip to Group 20.

Group 18: (3F12.1) HM(I), RHOM(I), EM(I)

Distance (h) from inner shell surface in the outer surface of layer I, in. (HM(I))

Mass density of layer I, $\text{lb-sec}^2/\text{in}^4$. (RHOM(I))

Modulus of elasticity, psi. (EM(I))

Repeat Group 18 for I=1, NL.

Group 19: (4F12.1) TNU, SIGO, EP, EPSIF

Poisson's ratio. (TNU)

Yield stress for a metal panel, psi. (SIGO)

Strain hardening modulus (E_t), psi. (EP)

Ultimate strain, in/in. (EPSIF)
(not necessary)

Group 20: (6F12.1) ((FG(N,M), N=1,MB), M=1,MG)

Modal displacement coefficients for initial radial imperfections, in. (FG(N,M))

Group 21: (3F12.1) DELTIM, TSTOP, PRINT

Integration time increment, sec. If DELTIM=0.0, the program determines the time increment required for stability. (DELTIM)

Integration stop time, sec. (TSTOP)

Print frequency (integration steps per printout). If PRINT=0.0, printout of intermediate data will be suppressed. (PRINT)

If KDS=2, skip Group 22.

Group 22: (F12.1) PS

Uniform static pressure load, psi. Can be either positive or negative value.

If KDS=1, skip Groups 23-33.

Group 23: (I12) NLOAD

Dynamic load option

1, special Eglin analytical function over space and time. (See Figure 6.)
2, discrete point by point, time by time distribution
3, spatially uniform, with an analytical function for time history. (See Figure 7.)
4, spatially uniform, with a discrete time history.

If NLOAD=2, skip to Group 25.

If NLOAD=3, skip to Group 31.

If NLOAD=4, skip to Group 32.

Group 24: (2F12.1) ZEE, PHI

Distance of detonation from panel, Z, in. (ZEE)

Angle projectile trajectory makes with the normal to the panel (z-axis), ϕ, degrees. (PHI)

Skip Groups 25-33

Group 25: (3I12) NPX, NPY, NTIME

Number of spatial points in the gamma-direction at which pressures are to be specified. (NPX) (Must be at least 2)

Number of spatial points in the beta-direction at which pressures are to be specified. (NPY) (Must be at least 2)

Number of times specified in the pressure-time history. (NTIME) ($2 \le \text{NTIME} \le 6$)

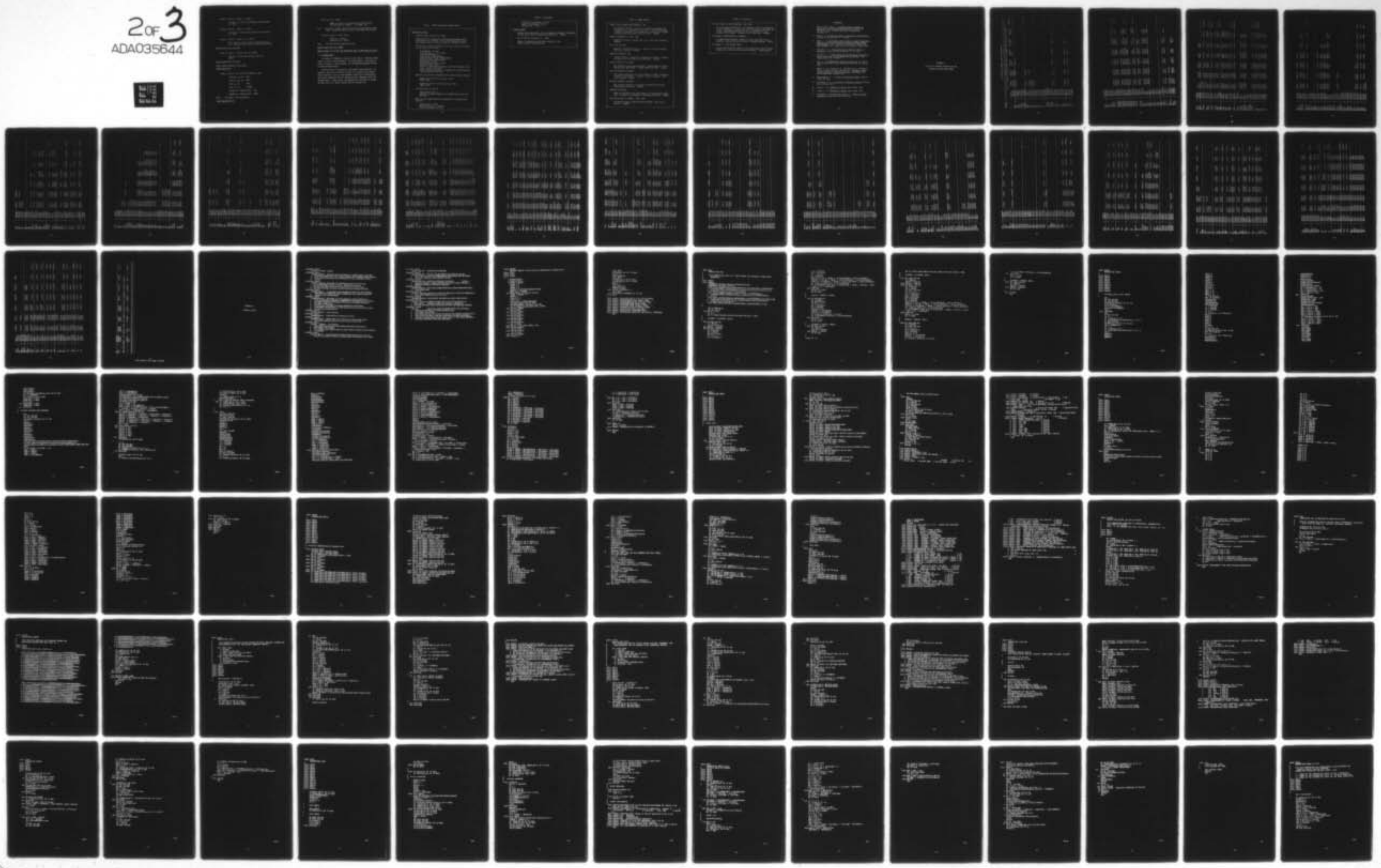
Group 26: (F12.1) DTIM

Time interval between samplings (DTIM). The time history for each point has the same time interval, but distinct delay times (Group 29)

Note: Be sure to allow for first point to be engulfed at time=0. Program will extrapolate data past last time in table.

AD-A035 644 KAMAN AVIDYNE BURLINGTON MASS F/G 1/3
DEPROP - A DIGITAL COMPUTER PROGRAM FOR PREDICTING DYNAMIC ELAS--ETC(U)
JUN 76 L J MENTE, W N LEE F08635-76-C-0162
UNCLASSIFIED KA-TR-133 AFATL-TR-76-71 NL

2 OF 3
ADA035644



Group 27: (6F12.1) (XP(I), I=1, NPX)

x-positions at which time histories are specified, in. (XP)

Group 28: (6F12.1) (YP(I), I=1, NPY)

y-positions at which time histories are specified, in. (YP)

Group 29: (6F12.1) (DET(J,I), J=1, NPY)

Delay time for pressure wave to reach grid point, sec (DET) (One point must have delay time of zero)

Repeat Group 29 for I=1, NPX.

Group 30: (6F12.1) (PRT(K,J,I), K=1, NTIME)

Pressure for each time and grid point, psi (PRT).

Repeat Group 30 for J=1, NPY.

Repeat Group 30 again, for I=1, NPX.

Skip Groups 31-33

Group 31: (6I12) PP1, PPO, TTO, TPRIME, AA, ANN

Pressure, p_1, psi	(PP1)
Pressure, p_0, psi	(PPO)
Time, t_0, sec	(TTO)
Time, t', sec	(TPRIME)
Parameter a, dimensionless	(AA)
Parameter n, dimensionless	(ANN)

Note: See Figure 7 for definitions.

Skip Groups 32 and 33

Group 32: (I12) NTIME

Number of points to be specified in point-by-point load description (NTIME). ($2 \leq NTIME \leq 20$).

Note: Be sure to include time=0 and also an end time which exceeds TSTOP. Otherwise, the last value in the table will be used.

Group 33: (2F12.1) TT(I), PT(I)

Time, sec. (TT(I))
Pressure, psi. (PT(I))

Note: One time and one pressure per card.

Repeat Group 33 for I=1, NTIME

Repeat Groups 2 to 33 for each additional case, as specified in Group 1

3.5 Program Output

The output for DEPROP is directed to the printer. Although program output is largely self-explanatory, the normal output is described in detail in Table 8. Where possible, the corresponding program variable is given parenthetically.

Certain errors, if detected by the program during execution, are brought to the user's attention by means of a printed error message. Table 9 provides a list of such messages, along with an indication of the routine associated with the message and the subsequent action the program takes. In most cases, the program will cycle back to attempt the next case if it cannot continue with the current one.

TABLE 8. DEPROP STRUCTURAL RESPONSE OUTPUT

Time-History Output

Time from shock arrival, sec (TIME)

Normalized axial, tangential, and radial displacement modal coefficients for all modes, with the beta mode index varying most rapidly ((UU(J,I), VV(J,I), WW(J,I), J=1,MB), I=1,MG)

Table of stress-strain information for inner and outer surfaces at each grid point selected:

X coordinate, in. (XG)
Beta position, in. or deg (XB)
Depthwise position, in.
Axial strain, dimensionless
Circumferential strain, dimensionless
Shearing strain, dimensionless
Axial stress, lb/in^2
Circumferential stress, lb/in^2
Shearing stress, lb/in^2
Flag ("*") indicating equivalent strain has exceeded yield strain (elastic runs only)
Counter indicating number of unloading and reyieldings (KY) (elastic-plastic runs only)

Table of reactive force information for each grid point selected:

Normal reactive force (V_x or V_θ), lb/in.
(VRX or VRT)

Tangential reactive force (N_x or N_θ), lb/in.
(ENX or ENT)

Reactive forces at corners:

Reactive force (R), lb
(omitted for panels clamped on all edges since forces are all zero).

Table of displacement-pressure information at each grid point selected:

X-coordinate, in (XG)
Beta-position, in or deg (XB)
Axial displacement, in (UF)

TABLE 8. (Concluded)

Tangential displacement, in (VF)
Radial displacement, in (WF)
Pressure, psi (PPP)

Summary Output

Message indicating whether run was terminated normally or abnormally, and the time at which computations stopped, sec (TIME)

Net CP time for response, sec (CPT)

Number of integration points which yielded, if any (Elastic-plastic response only)

TABLE 9. ERROR MESSAGES

CANNOT TOTALLY CORRECT FOR OVERSHOOT. XXX

An iterative process to correct for overshoot associated with yielding has not converged in five trials. This probably means a numerical instability is creeping into the solution. Program continues until such errors occur 100 times. (SIGMA)

DEPROP IS ABORTED AT T, SEC = XXX.

DEPROP cycles back to attempt next case. This case is aborted. (DEPROP)

EPP IS OUT OF RANGE

Numerical instability detected. A smaller Δt may be required. This case is aborted. (SIGMA)

IMMEDIATE RELOADING, XXX.

Probable numerical instability creeping into solution. Program continues until such errors occur 100 times. (SIGMA)

SINGULAR MATRIX IN S/R SOLVE.

The relaxation process has generated a singular matrix in determining static equilibrium. Program aborts this case. (SOLVE)

SOLUTION DIVERGING IN DEPROP.

Very large accelerations have been computed in DERV2, indicating a numerical instability. A smaller Δt may be required. This case is aborted. (DERV2)

SOLUTION DIVERGING IN RELAXP.

The iterative process to find static equilibrium has failed. Program aborts this case. (RELAXP)

SOLUTION IS UNSTABLE.

Numerical instability has been detected in elastic-plastic solution. A smaller Δt is required. This case is aborted. (SIGMA)

THE VALUE OF LBAR IS INVALID. LBAR = XXX.

An incorrect value of LBAR has been specified. This case is aborted. (LEGEND)

TABLE 9. (Concluded)

TOO MANY TRIALS IN STATIC SOLUTION. MTR = XXX.

To avoid looping indefinitely in attempting a solution representing static equilibrium, an upper limit of 10 is placed on the number of trials. Program may need more trials and adjustment of the variable CON in RELAXP. Program cycles to next case. (DEPROP)

** WARNING ** INCONSISTENCY IN SYMMETRY

A clamped-simple boundary condition has been specified, while a symmetric solution has been indicated. Program continues. (DSET3)

** WARNING ** - TIME EXCEEDS TABLE

Either TSTOP should be reduced as the time-pressure table extended. Program uses last value in table and continues. (Load Option 4)

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APPENDIX A

LIST OF ALL PROGRAM VARIABLES AND THE ROUTINES IN WHICH THEY APPEAR

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********** SUPER INDEX **********

SYMBOL   - ==================  ROUTINES IN WHICH THE SYMBOL APPEARS  ==================
                  (AN * FOLLOWS ALL ROUTINE NAMES IN WHICH THE SYMBOL IS USED.)

A        -  BOLT      DERV2     DSET1*    DSET2*    DSET3*    DISTEP*   LEGEND    LIST1*
            LIST2*    PINIT     PRESS     PROF      REIT      SIGMA     SOLVE*
AA       -  DEPROF    PINIT*    PRESS
ABS      -  DERV2*    RELAXF*   SIGMA*    SOLVE*
AC       -  DERV2*
ALTT     -  SIGMA*
ALXT     -  SIGMA*
ALXX     -  SIGMA*
AMIN1    -  DISTEP*
ANN      -  DEPROF    PINIT*    PRESS*
AX4      -  HIM*
AZ       -  DEPROF    PINIT*    PRESS*
A1       -  DSET2*    SIGMA*
A2       -  DSET2*    SIGMA*
A3       -  DSET2*    SIGMA*
A4       -  DSET2*
A5       -  DSET2*
A6       -  DSET2*
A7       -  DSET2*
A8       -  DSET2*
B        -  SOLVE*
BARM     -  DISTEP*
BARMX    -  DISTEP*
BARN     -  DISTEP*
BARNX    -  DISTEP*
BETR     -  BOLT*     DERV2     DSET1     DSET2     DSET3*    DISTEP    PROF
BE1      -  SIGMA*
BE2      -  SIGMA*
BE3      -  SIGMA*
BM       -  DISTEP*
BN       -  DISTEP*
BOLT     -  DSET3*
BTL      -  DSET1     DSET2*    DSET3     LIST1*    LIST2     PROP
BTT      -  DSET2*
BXL      -  DSET1     DSET2*    DSET3     LIST1*    LIST2     PROP
BXX      -  DSET2*
B1       -  SIGMA*
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B11       -  DSET2*
B12       -  DSET2*
P2        -  SIGMA*
B22       -  DSET2*
B33       -  DSET2*
CALPH     -  PRESS*
CBLK1     -  BOLT*      DERV2*     DSET1*     DSET2*     DSET3*     DTSTEP*    LEGEND*    LIST1*
             LIST2*     PINIT*     PRESS*     PROP*      REIT*      SIGMA*
CBLK10    -  DERV2*     DSET1*     DSET2*     DSET3*     LIST1*     LIST2*     PROP*      REIT*
CBLK11    -  DERV2*     DSET1*     DSET2*     DSET3*     PROP*      REIT*
CBLK12    -  RELAXP*
CBLK13    -  DSET1*     DSET2*     DSET3*     DTSTEP*    PROP*
CBLK14    -  DERV2*     DSET1*     DSET3*     LIST1*     LIST2*     PROP*      REIT*
CBLK2     -  BOLT*      DERV2*     DSET1*     DSET2*     DSET3*     DTSTEP*    PROP*
CBLK3     -  DERV2*     DSET1*     DSET2*     DSET3*     LEGEND*    PROP*      REIT*      SIGMA*
CBLK4     -  DERV2*     DSET1*     DSET2*     DSET3*     PROP*      SIGMA*
CBLK5     -  DSET1*     DSET2*     DSET3*     PROP*
CBLK6     -  SIGMA*
CBLK7     -  DSET1*     DSET2*     DSET3*     LIST2*     PROP*      REIT*      SIGMA*
CBLK8     -  DERV2*     DSET1*     DSET2*     DSET3*     LIST1*     LIST2*     PINIT*     PRESS*
             PROP*
CBLK9     -  DSET1*     DSET2*     DSET3*     LIST1*     LIST2*     PROP*
CCFIT     -  DSET1      DSET2*     DSET3      LIST1      LIST2      PROP
CCX       -  LEGEND*
CC1       -  BOLT       DERV2*     DSET1*     DSET2      DSET3      DTSTEP     PROP
CC2       -  BOLT       DERV2*     DSET1*     DSET2      DSET3      DTSTEP     PROP
CC5       -  BOLT       DERV2*     DSET1*     DSET2      DSET3      DTSTEP     PROP
CC6       -  BOLT       DERV2*     DSET1*     DSET2      DSET3      DTSTEP     PROP
CDA       -  BOLT*
CDL       -  BOLT*
CD1       -  BOLT*
CD2       -  BOLT*
CD3       -  BOLT*
CD4       -  BOLT*
CHIM      -  HIM*
CHO       -  LEGEND*
CINST     -  DSET1      DSET2      DSET3      LIST1      LIST2      PROP
CK        -  BOLT*      DERV2*     DSET1      DSET2      DSET3      DTSTEP     PROP
CL        -  BOLT*
CLOAD     -  DEPROF*    PINIT*     PRESS*
CM        -  DERV2*     DTSTEP*
CM11      -  DERV2*     DSET1      DSET2*     DSET3      PROP       REIT*
CM12      -  DERV2*     DSET1      DSET2*     DSET3      PROP       REIT*
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CM2      -  DERV2*
CM22     -  DERV2*   DSET1    DSET2*   DSET3    PROP     REIT*
CM33     -  DERV2*   DSET1    DSET2*   DSET3    PROP     REIT
CN       -  DERV2*   DTSTEP*
CNOVA    -  DERPROP* DERV2*   DSET1*   DSET2*   DSET3*   DTSTEP*  LIST1*   LIST2*
            FINIT*   PRESS*   PROP*    SIGMA*
CN1      -  DSET1    DSET2    DSET3    LIST2    PROP     REIT     SIGMA*
CN10     -  DERV2*   DSET1    DSET2    DSET3*   LIST1    LIST2    FINIT    PRESS
            PROP     REIT     SIGMA
CN11     -  DERV2*   DSET1    DSET2    DSET3*   LIST1    LIST2    FINIT    PRESS
            PROP     REIT     SIGMA
CN12     -  DSET1    DSET2    DSET3    LIST2    PROP     REIT     SIGMA*
CN13     -  DSET1    DSET2    DSET3    LIST2    PROP     REIT     SIGMA*
CN2      -  DERV2*   DSET1    DSET2    DSET3    LIST2    PROP     REIT     SIGMA*
CN22     -  SIGMA*
CN3      -  DSET1    DSET2    DSET3    LIST2    PROP     REIT     SIGMA*
CN4      -  DSET1    DSET2    DSET3    LIST2    PROP     REIT     SIGMA*
CN5      -  DSET1    DSET2    DSET3    LIST2    PROP     REIT     SIGMA*
CN6      -  DSET1    DSET2    DSET3    LIST2    PROP     REIT     SIGMA*
CN7      -  DSET1    DSET2    DSET3    LIST2    PROP     REIT     SIGMA*
CN8      -  DERV2*   DSET1    DSET2    DSET3*   LIST1    LIST2    FINIT    PRESS
            PROP     REIT     SIGMA
CN9      -  DERV2*   DSET1    DSET2    DSET3*   LIST1    LIST2    FINIT    PRESS
            PROP     REIT     SIGMA
CON      -  RELAXP*
COS      -  BOLT*    DSET3*
COSB     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
COSG     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
COS23    -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
COS2G    -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
CPT      -  PROP*
CPTIM1   -  PROP*
CPTIM3   -  PROP*
CPIT     -  DERPROP  DERV2    DSET1    DSET2    DSET3    DTSTEP   LIST1    LIST2
            FINIT    PRESS    PROP*    SIGMA
C1       -  DERV2    DSET1    DSET3*   LIST1    LIST2    PROP     REIT*    SIGMA*
C2       -  DERV2    DSET1    DSET3*   LIST1    LIST2    PROP     REIT*    SIGMA*
C3       -  DERV2    DSET1    DSET3*   LIST1    LIST2    PROP     REIT*    SIGMA*
C4       -  DERV2    DSET1    DSET3*   LIST1    LIST2    PROP     REIT*
C5       -  DERV2    DSET1    DSET3*   LIST1    LIST2    PROP     REIT*
C6       -  DERV2    DSET1    DSET3*   LIST1    LIST2    PROP     REIT
C7       -  DERV2    DSET1    DSET3    LIST1    LIST2    PROP     REIT
```

```
DC       -  DSET1*   DSET2    DSET3*   DTSTEP   PROP
DFLEP    -  SIGMA*
DELT     -  DERV2    DSET1    DSET3*   LIST1    LIST2    PROP     REIT*
DELTIM   -  DFPROF   DERV2    DSET1*   DSET2*   DSET3*   DTSTEP*  HIM*     LIST1
            LIST2    PINIT    PRESS    PROP*    SIGMA
DELTT    -  REIT*
DELX     -  DERV2    DSET1    DSET3*   LIST1    LIST2    PROP     REIT*    RELAXP*
DELXX    -  REIT*
DEL1     -  SIGMA*
DEL2     -  SIGMA*
DEL3     -  SIGMA*
DERV2    -  PROP*
DET      -  DEPROF   PINIT*   PRESS*   RELAXP*  SOLVE*
DETT     -  PRESS*
DM11     -  DERV2*   DSET1    DSET2*   DSET3*   PROP     REIT
DM12     -  DERV2*   DSET1    DSET2*   DSET3*   PROP     REIT
DM22     -  DERV2*   DSET1    DSET2*   DSET3*   PROP     REIT
DM33     -  DERV2*   DSET1    DSET2*   DSET3*   PROP     REIT
DPRT     -  BOLT     DERV2*   DSET1    DSET2    DSET3    DTSTEP   PROP*
DPRT1    -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
DSET1    -  PROP*
DSET2    -  PROP*
DSET3    -  PROP*
DT       -  DSET2*
DTIM     -  DFPROF   PINIT*   PRESS*
DTSQ     -  HIM*
DTSTEP   -  DSET2*
DT1      -  DTSTEP*
DT1X     -  DTSTEP*
DT2      -  DTSTEP*
DT2X     -  DTSTEP*
DT3X     -  DTSTEP*
DT4X     -  DTSTEP*
DT5      -  DTSTEP*
DTEX     -  DTSTEP*
DUM      -  DTSTEP*  PRESS*   PROP*    SEC*
DWB      -  DERV2*   DSET1    DSET2    DSET3*   LIST1    LIST2    PROP     REIT
DWBF     -  DERV2*
DWG      -  DERV2*   DSET1    DSET2    DSET3*   LIST1    LIST2    PROP     REIT
DWGF     -  DERV2*
DWO      -  DERV2*   DSET1    DSET2    DSET3*   LIST1    LIST2    PROP     REIT
DX       -  PRESS*   RELAXP*
```

```
DX1      -  DEPROP    FINIT*    PRESS*
DY       -  PRESS*
DY1      -  DEPROP    FINIT*    PRESS*
D1       -  DSET2*    SIGMA*
D2       -  DSET2*    SIGMA*
D3       -  SIGMA*
D4       -  SIGMA*
D5       -  SIGMA*
D6       -  SIGMA*
EC       -  DSET1*    DSET2     DSET3*    DISTEF    PROP
EKMN     -  DISTEF*
EL       -  DSET1     DSET2*    DSET3*    LIST2     PROP      REIT      SIGMA*
ELMN     -  DISTEP*
EM       -  DSET1*    DSET2*    DSET3     PROP
ENT      -  DERV2     DSET1     DSET3     LIST1*    LIST2*    PROP      REIT*
ENX      -  DERV2     DSET1     DSET3     LIST1*    LIST2*    PROP      REIT*
EP       -  DSET1*    DSET2*    DSET3*    LIST2     PROP      REIT      SIGMA*
EPB      -  SIGMA*
EPBD     -  SIGMA*
EPROP    -  SIGMA*
EPRO     -  DERV2     DSET1     DSET2     DSET3     LIST1     LIST2*    FINIT     PRESS
            PROP      REIT      SIGMA*
EPQ      -  DSET1     DSET2     DSET3     LIST2     PROP      REIT      SIGMA*
EPR      -  DSET1     DSET2     DSET3     LIST2     PROP      REIT      SIGMA*
EPSIF    -  DSET1*    DSET2*    DSET3*    DISTEF    PROP
EQC      -  DSET2*
EQH      -  DSET2*
ERR      -  DSET1     DSET2     DSET3     PROP*     RELAXP*
ERRS     -  PROP*
ET       -  DSET1*    DSET2*    DSET3*    LIST1     LIST2     PROP
ETT      -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    FINIT     PRESS
            PROP      REIT*     SIGMA*
ETT1     -  SIGMA*
EX       -  DSET1*    DSET2*    DSET3*    LIST1     LIST2     PROP
EXP      -  POLT*     FINIT*    PRESS*
EXT      -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    FINIT     PRESS
            PROP      REIT      SIGMA*
EXT1     -  SIGMA*
EXX      -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    FINIT     PRESS
            PROP      REIT*     SIGMA*
EXX1     -  SIGMA*
EX1      -  POLT*
```

```
EX2     -  BOLT*
E1      -  SIGMA*
E2      -  SIGMA*
E3      -  SIGMA*
F       -  DSET2*   DSET3*
FAC     -  BOLT*    PRESS*
FG      -  DSET1*   DSET2    DSET3*   PROP
FGMN    -  DSET3*
FIRST   -  DEPROP*  PROP*
FLAG    -  LIST1*   LIST2*
FLOAT   -  DSET3*   PRESS*
FL1     -  LIST1*   LIST2*
FL2     -  LIST1*   LIST2*
FM11    -  DERV2*   DSET1    DSET2*   DSET3    PROP     REIT
FM12    -  DERV2*   DSET1    DSET2*   DSET3    PROP     REIT
FM22    -  DERV2*   DSET1    DSET2*   DSET3    PROP     REIT
FM33    -  DERV2*   DSET1    DSET2*   DSET3    PROP     REIT
FP1     -  BOLT*    DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
FP2     -  BOLT*    DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
FP3     -  BOLT*    DERV2*   DSET1    DSET2    DSET3    DTSTEP   PROP
FP4     -  BOLT*    DERV2*   DSET1    DSET2    DSET3    DTSTEP   PROP
FP5     -  BOLT*    DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
FP6     -  BOLT*    DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
FP7     -  BOLT*    DERV2*   DSET1    DSET2    DSET3    DTSTEP   PROP
FP8     -  BOLT*    DERV2*   DSET1    DSET2    DSET3    DTSTEP   PROP
FU      -  DERV2*
FV      -  DERV2*
FW      -  DERV2*
F1      -  DERV2*   DSET2*   DTSTEP*
F2      -  DERV2*   DSET2*   DTSTEP*
F3      -  DERV2*   DSET2*   DTSTEP*
F4      -  DERV2*   DSET2*   DTSTEP*
F5      -  DERV2*   DSET2*   DTSTEP*
F6      -  DERV2*
GAM     -  BOLT*    DERV2    DSET1    DSET2    DSET3*   DTSTEP   PROP
GAMMA   -  DEPROP   DERV2    DSET1    DSET2    DSET3    DTSTEP   LIST1    LIST2
           PINIT    PRESS    PROP     SIGMA
GC      -  DSET1*   DSET2    DSET3*   DTSTEP   PROP
GX      -  DERV2*   DSET1    DSET2    DSET3*   LEGEND*  PROP     REIT*    SIGMA
GXT     -  DSET1*   DSET2*   DSET3*   LIST1*   LIST2    PROP
GXTL    -  DSET2*
```

```
G1       -  DERV2*    REIT*     SIGMA*
G11      -  REIT*
G2       -  DERV2*    REIT*     SIGMA*
G22      -  REIT*
G3       -  DERV2*    REIT*     SIGMA*
G31      -  REIT*
G32      -  REIT*
G4       -  DERV2*
G5       -  DERV2*
G6       -  DERV2*
H        -  DSET1     DSET2*    DSET3*    LIST2     PROF      REIT*     SIGMA
HBAR     -  DSET1     DSET2*    DSET3*    DISTEF    PROF
HB11     -  DSET2*
HB12     -  DSET2*
HB22     -  DSET2*
HB33     -  DSET2*
HD1      -  DSET2*
HD2      -  DSET2*
HG0      -  DERV2*    DSET1     DSET2     DSET3     LEGEND*   PROP      REIT*     SIGMA
HIM      -  PROF*
HM       -  DSET1*    DSET2*    DSET3*    PROF
HS       -  DSET2*
HT       -  DSET2*
H0       -  DSET2*
H1       -  DSET2*    SIGMA*
H11      -  DSET2*
H12      -  DSET2*
H12D     -  DSET2*
H13      -  DSET2*
H13D     -  DSET2*
H2       -  DSET2*    SIGMA*
H3       -  SIGMA*
H4       -  SIGMA*
I        -  BOLT*     DERROF*   DERV2*    DSET1*    DSET2*    DSET3*    HIM*      LIST1*
            LIST2*    PINIT*    PRESS*    REIT*     RELAXP*   SIGMA*    SOLVE*
IABS     -  DERV2*
ICOMP    -  DERROF*   DERV2     DSET1     DSET2     DSET3     DISTEP    LIST1     LIST2
            PINIT     PRESS     PROP      SIGMA
ICOUNT   -  DERROF*   PROF*
IFIRST   -  DSET1     DSET2     DSET3     LIST2     PROF*     REIT      SIGMA*
II       -  BOLT*     DERV2*    DSET3*    LIST1*    PRESS*    SIGMA*
III      -  PINIT*
```

```
IJ       -  SIGMA*
INOUT    -  DEPROP*    DERV2      DSET1*     DSET2      DSET3      DTSTEP     LIST1      LIST2
            PINIT      PRESS      PROP       SIGMA
INZ      -  DERV2      DSET1      DSET2      DSET3*     LIST1      LIST2*     PINIT      [illegible]
            PROP       REIT       SIGMA
IP       -  RELAXP*    SOLVE*
IPHI     -  PINIT*
IR       -  DERV2*
IS       -  DERV2*
IXI      -  DEPROP     PINIT*     PRESS*
IZ       -  DERV2*
J        -  BOLT*      DERV2*     DSET1*     DSET3*     LEGEND*    LIST1*     LIST2*     PINIT*
            PRESS*     PROP*      REIT*      SIGMA*     SOLVE*
JFIRST   -  DSET1      DSET2      DSET3      LIST2      PROP*      REIT       SIGMA*
JI       -  DERV2*     LIST2*     REIT*
JI1      -  REIT*
JI2      -  REIT*
JJ       -  DERV2*     PRESS*
JJJ      -  PINIT*
JL       -  DEPROP     PINIT*     PRESS*
JLT      -  DEPROP     PINIT*     PRESS*
JYJ      -  DEPROP     PINIT*     PRESS*
K        -  DERV2*     DSET3*     HIM*       LIST1*     LIST2*     PINIT*     PRESS*     REIT*
            SIGMA*     SOLVE*
KALT     -  DEPROP     DERV2      DSET1      DSET2      DSET3      DTSTEP     LIST1      LIST2
            PINIT      PRESS      PROP       SIGMA
KB       -  DEPROP     DERV2      DSET1      DSET2      DSET3      DTSTEP     LIST1      LIST2
            PINIT      PRESS      PROP       SIGMA      SOLVE*
KC       -  BOLT       DERV2*     DSET1      DSET2      DSET3      DTSTEP     PROP*
KDAM     -  DEPROP*    DERV2*     DSET1*     DSET2*     DSET3*     DTSTEP     LIST1      LIST2
            PINIT      PRESS      PROP*      SIGMA
KOS      -  DEPROP*    DERV2      DSET1      DSET2      DSET3      DTSTEP     LIST1      LIST2
            PINIT*     PRESS      PROP*      SIGMA
KERR     -  DEPROP*    DERV2*     DSET1      DSET2*     DSET3      DTSTEP     LIST1      LIST2
            PINIT      PRESS      PROP*      SIGMA*
KEY      -  SIGMA*
KHIM     -  PROP*
KK       -  DERV2*     LIST2*     PRESS*     REIT*
KKK      -  LIST1*     LIST2*
KM1      -  SOLVE*
KOK      -  DEPROP*    DERV2      DSET1      DSET2      DSET3      DTSTEP     LIST1      LIST2
            PINIT      PRESS      PROP       SIGMA
```

```
KPB      -  DERV2     DSET1*    DSET3*    LIST1     LIST2     PROP      REIT
KPG      -  DERV2     DSET1*    DSET3*    LIST1     LIST2     PROP      REIT
KP1      -  SOLVE*
KSUM     -  DERV2*    SIGMA*
KSUMA    -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2     PINIT     PRESS
            PROF      REIT      SIGMA*
KTYPE    -  DEPROP*   DERV2     DSET1*    DSET2*    DSET3*    DTSTEP    LIST1     LIST2
            PINIT     PRESS     PROF      SIGMA
KY       -  DERV2     DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROF*     REIT      SIGMA*
KZ       -  BOLT      DERV2*    DSET1     DSET2     DSET3     DTSTEP    LEGEND    LIST1*
            LIST2*    PINIT     PRESS     PROF*     REIT      SIGMA
K1       -  REIT*
K2       -  REIT*
L        -  DERV2*    LIST2*    PROF*     REIT*     SIGMA*
LBAR     -  BOLT      DERV2*    DSET1*    DSET2*    DSET3*    DTSTEP    LEGEND*   LIST1
            LIST2*    PINIT     PRESS     PROF      REIT*     SIGMA*
LC       -  DSET1     DSET2     DSET3     LIST2     PROF      REIT      SIGMA*
LCMAX    -  DSET1     DSET2     DSET3     LIST2     PROF      REIT      SIGMA*
LEGEND   -  DSET2*
LIST1    -  DERV2*    PROF*
LIST2    -  DERV2*    PROF*
LMAX     -  BOLT      DERV2     DSET1     DSET2     DSET3*    DTSTEP    LEGEND    LIST1
            LIST2     PINIT     PRESS     PROF*     REIT      SIGMA*
L1       -  REIT*
L2       -  REIT*
M        -  BOLT*     DERV2*    DSET1*    DSET3*    DTSTEP*   LEGEND*   LIST1*    LIST2*
            PINIT*    PROF*     SIGMA*    SOLVE*
MB       -  BOLT*     DERV2*    DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1*
            LIST2*    PINIT     PRESS     PROF*     REIT      SIGMA
MBAR     -  BOLT*     DERV2*    DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1*
            LIST2*    PINIT     PRESS     PROF      REIT      SIGMA
MG       -  BOLT*     DERV2*    DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1*
            LIST2*    PINIT     PRESS     PROF*     REIT      SIGMA
MGM      -  BOLT*     DERV2     DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1*
            LIST2*    PINIT     PRESS     PROF      REIT      SIGMA
MGMB     -  BOLT      DERV2*    DSET1*    DSET2     DSET3*    DTSTEP    LEGEND    LIST1
            LIST2     PINIT     PRESS     PROF*     REIT      SIGMA
MGMB2    -  BOLT      DERV2*    DSET1*    DSET2     DSET3     DTSTEP    LEGEND    LIST1
            LIST2     PINIT     PRESS     PROF*     REIT      SIGMA
MM       -  DERV2*    DSET1*    DSET3*    RELAXE*
MMU      -  DERV2*
```

```
MOUT      -  DSET1*    DSET2     DSET3     PROP
MIR       -  PROF*
MTRMAX    -  PROF*
MUSE      -  BOLT      DERV2*    DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1*
             LIST2*    PINIT     PRESS     PROP*     REIT      SIGMA
N         -  BOLT*     DERV2*    DSET1*    DSET2*    DTSTEP*   LEGEND*   LIST1*    LIST2*
             PROF*     RELAXP*   SOLVE*
NB        -  BOLT      DERV2     DSET1     DSET2     DSET3*    DTSTEP    LEGEND    LIST1
             LIST2     PINIT*    PRESS     PROP      REIT      SIGMA
NBAR      -  BOLT*     DERV2*    DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1*
             LIST2*    PINIT     PRESS     PROP      REIT      SIGMA
NBC       -  DERV2*    LIST1*    LIST2*    REIT*
NBN       -  BOLT*     DERV2     DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1*
             LIST2*    PINIT     PRESS     PROP      REIT      SIGMA
NBND      -  BOLT*     DERV2     DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1*
             LIST2*    PINIT     PRESS     PROP      REIT      SIGMA
NBT       -  BOLT*     DERV2*    DSET1     DSET2     DSET3*    DTSTEP    LEGEND    LIST1*
             LIST2*    PINIT*    PRESS*    PROP      REIT*     SIGMA
NBUSE     -  DERV2*    DSET1     DSET3*    LIST1*    LIST2*    PROP      REIT*
NC        -  LIST1*    LIST2*    SIGMA*
NCALL     -  DEPROP*   DERV2*    DSET1     DSET2     DSET3     DTSTEP    LIST1*    LIST2*
             PINIT     PRESS*    PROP*     SIGMA
NCASE     -  DEPROP*   DERV2     DSET1     DSET2     DSET3     DTSTEP    LIST1     LIST2
             PINIT     PRESS     PROP*     SIGMA
NCASES    -  DEPROP*
NCHPT     -  DEPROP    DERV2     DSET1     DSET2     DSET3     DTSTEP    LIST1     LIST2
             PINIT     PRESS     PROP      SIGMA
NCOUNT    -  PROP*     RELAXP*
NDBUG     -  DEPROP*   DERV2     DSET1     DSET2     DSET3     DTSTEP*   LIST1     LIST2
             PINIT     PRESS     PROP*     SIGMA
NDERV     -  BOLT      DERV2*    DSET1*    DSET2*    DSET3*    DTSTEP    LEGEND    LIST1
             LIST2     PINIT     PRESS     PROP*     REIT*     SIGMA
NDET      -  SOLVE*
NDIM      -  SOLVE*
NELP      -  DSET1     DSET2*    DSET3     LIST2*    PROP*     REIT      SIGMA*
NEQ       -  HIM*      RELAXP*
NEV       -  LEGEND*
NG        -  BOLT      DERV2     DSET1     DSET2     DSET3*    DTSTEP    LEGEND    LIST1
             LIST2     PINIT*    PRESS     PROP      REIT      SIGMA
NGNB      -  BOLT      DERV2     DSET1     DSET2     DSET3*    DTSTEP    LEGEND    LIST1
             LIST2     PINIT     PRESS     PROP      REIT      SIGMA
NGNBT     -  BOLT      DERV2     DSET1     DSET2     DSET3*    DTSTEP    LEGEND    LIST1
             LIST2     PINIT     PRESS     PROP      REIT      SIGMA
```

```
NGT        -  BOLT*     DERV2*    DSET1     DSET2     DSET3*    DTSTEP    LEGEND    LIST1*
              LIST2*    PINIT*    PRESS*    PROP      REIT      SIGMA
NKP        -  DERV2     DSET1*    DSET3*    LIST1*    LIST2*    PROP      REIT
NL         -  DSET1*    DSET2*    DSET3*    DTSTEP    PROP
NLOAD      -  DEPROP    PINIT*    PRESS*
NLZ        -  DSET1     DSET2*    DSET3     LIST1*    LIST2     PROP
NMASS      -  DEPROP    DERV2     DSET1     DSET2     DSET3     DTSTEP    LIST1     LIST2
              PINIT     PRESS     PROP      SIGMA
NM1        -  SOLVE*
NN         -  DERV2*    DSET1*    DSET3*
NNELP      -  PROP*
NNO        -  DERV2*
NNOUT      -  DSET1*    DSET2     DSET3     DTSTEP    PROP
NNQ        -  RELAXP*
NNSYMB     -  DSET3*
NNSYMG     -  DSET3*
NNUSE      -  LIST1*    LIST2*
NOK        -  PROP*     RELAXP*
NOUT       -  DSET1*    DSET2     DSET3     PROP
NPLT       -  BOLT      DERV2*    DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1*
              LIST2*    PINIT     PRESS     PROP      REIT      SIGMA
NPRINT     -  RELAXP*
NPX        -  DEPROP    PINIT*    PRESS*
NPY        -  DEPROP    PINIT*    PRESS*
NQ         -  RELAXP*
NRC        -  DERV2     DSET1     DSET3*    LIST1*    LIST2*    PROP      REIT
NREG       -  DSET1     DSET2     DSET3     LIST1     LIST2     PROP*
NS         -  PROP*
NSYMB      -  BOLT      DERV2*    DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1
              LIST2     PINIT     PRESS     PROP      REIT      SIGMA
NSYMG      -  BOLT      DERV2*    DSET1*    DSET2     DSET3*    DTSTEP*   LEGEND    LIST1
              LIST2     PINIT     PRESS     PROP      REIT      SIGMA
NTECO      -  DSET1     DSET2     DSET3     LIST1     LIST2     PROP*
NTIME      -  DEPROP    PINIT*    PRESS*
NTR        -  PROP*
NTRIAL     -  DEPROP*   DERV2     DSET1     DSET2     DSET3     DTSTEP    LIST1     LIST2
              PINIT     PRESS     PROP*     SIGMA
NU         -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PINIT*    PRESS
              PROP*
NUSE       -  DERV2*    DSET1     DSET2     DSET3*    LIST1*    LIST2*    PINIT     PRESS*
              PROP      REIT      SIGMA
NY2        -  DERV2     DSET1     DSET2     DSET3*    PROP*     SIGMA
```

```
NZP      -  DSET1    DSET2*   DSET3    LIST1*   LIST2    PROP
N1       -  DSET3*
OA       -  DSET2*   DSET3*
OM3      -  DSET2*
OTTO     -  DEPROP   PINIT*   PRESS*
OTT1     -  DEPROP   PINIT*   PRESS*
O2A2     -  DSET2*
O3A3     -  DSET2*
P        -  DERV2*   DSET1    DSET2    DSET3    LIST1*   LIST2*   PINIT    PRESS*
            PROP
PB       -  DEPROP   DERV2    DSET1    DSET2    DSET3    DTSTEP   LIST1    LIST2
            PINIT    PRESS    PROP     SIGMA
PDAM     -  DEPROP   DERV2    DSET1    DSET2    DSET3    DTSTEP   LIST1    LIST2
            PINIT    PRESS    PROP     SIGMA
PETTU    -  DERV2*
PETTV    -  DERV2*
PETTW    -  DERV2*
PEXTU    -  DERV2*
PEXTV    -  DERV2*
PEXTW    -  DERV2*
PEXXU    -  DERV2*
PEXXV    -  DERV2*
PEXXW    -  DERV2*
PHI      -  DEPROP   PINIT*   PRESS
PI       -  BOLT     DERV2    DSET1*   DSET2    DSET3*   DTSTEP*  LEGEND   LIST1
            LIST2    PINIT    PRESS    PROP*    RETT     SIGMA
PIM      -  DSET3*
PIMA     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
PIN      -  DSET3*
PINA     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
PINIT    -  DEPROP*
PKTTU    -  DERV2*
PKTTV    -  DERV2*
PKTTW    -  DERV2*
PKXTU    -  DERV2*
PKXTV    -  DERV2*
PKXTW    -  DERV2*
PKXXU    -  DERV2*
PKXXV    -  DERV2*
```

```
PKXXW    -  DERV2*
PM       -  PRESS*
PPO      -  DEPROP     PINIT*     PRESS*
PPP      -  DEPROP     DERV2*     DSET1      DSET2      DSET3      DISTEP     LIST1*     LIST2*
            PINIT*     PRESS*     PROP*      SIGMA
PPRIME   -  PINIT*
PP1      -  DEPROP     PINIT*     PRESS*
PRES     -  RELAXP*
PRESS    -  DERV2*
PRINT    -  DEPROP     DERV2*     DSET1*     DSET2      DSET3*     DISTEP     LIST1      LIST2
            PINIT      PRESS      PROP       SIGMA
PRL      -  DSET3*
PRLM     -  DERV2*
PRLN     -  DERV2*
PROP     -  DEPROP*    RELAXP*
PRT      -  DEPROP     PINIT*     PRESS*
PRTT     -  DEPROP     PINIT      PRESS*
PS       -  PINIT*
PT       -  DEPROP     PINIT*     PRESS*
PU       -  DERV2*
PUB      -  DERV2*
PUG      -  DERV2*
PV       -  DERV2*
PVB      -  DERV2*
PVG      -  DERV2*
PW       -  DERV2*
PWB      -  DERV2*
PWBB     -  DERV2*
PWG      -  DERV2*
PWGB     -  DERV2*
PWGG     -  DERV2*
PX       -  RELAXP*
P1       -  PRESS*     SIGMA*
P2       -  PRESS*     SIGMA*
P3       -  SIGMA*
QQ1      -  PINIT*
QQ2      -  PINIT*
Q1       -  DEPROP     PINIT*     PRESS*     SIGMA*
Q2       -  DEPROP     PINIT*     PRESS*     SIGMA*
Q3       -  SIGMA*
R        -  DSET3*
RA       -  DERV2      DSET1      DSET2      DSET3      LIST1      LIST2      PINIT*     PRESS*
            PROP
```

```
REIT     -  DERV2*
RELAXP   -  PROF*
RES      -  RELAXP*
RETURN   -  PCLT*     DERV2*    DSET1*    DSET2*    DSET3*    DTSTEP*   HIM*      LEGEND*
            LIST1*    LIST2*    PINIT*    PRESS*    PROF*     REIT*     RELAXP*   SEC*
            SIGMA*    SOLVE*
RFP      -  DEPROP    DERV2     DSET1     DSET2     DSET3     DTSTEP    LIST1     LIST2
            PINIT     PRESS     PROF      SIGMA
RHO      -  DSET1     DSET2*    DSET3*    DTSTEP    PROF
RHOBR    -  DSET2*
RHOL     -  DSET2*
RHOM     -  DSET1*    DSET2*    DSET3*    PROF
RR       -  DERV2     DSET1     DSET3     LIST1*    LIST2*    PROP      REIT*
RRES     -  RELAXP*
RRR      -  PRESS*
RTRIAL   -  DEPROP*   DERV2     DSET1     DSET2     DSET3     DTSTEP    LIST1     LIST2
            PINIT     PRESS*    PROF*     SIGMA
SAC      -  DSET1*    DSET2*    DSET3*    LIST1*    LIST2     PROP
SAT      -  DSET1*    DSET2*    DSET3*    LIST1*    LIST2     PROP
SEC      -  PROF*
SECOND   -  SEC*
SIG      -  LIST1*
SIGBD    -  SIGMA*
SIGMA    -  DERV2*
SIGO     -  DSET1*    DSET2*    DSET3*    LIST2     PROF      REIT      SIGMA*
SIGO2    -  DSET1     DSET2     DSET3     LIST2*    PROF      REIT      SIGMA*
SIGTT    -  LIST1*
SIGTT1   -  SIGMA*
SIGX     -  RELAXP*
SIGXT    -  LIST1*
SIGXT1   -  SIGMA*
SIGXX    -  LIST1*
SIGXX1   -  SIGMA*
SIG1     -  LIST1*    LIST2*
SIG2     -  LIST1*    LIST2*
SIG3     -  LIST2*
SIN      -  BOLT*     DSET3*
SINB     -  BOLT      DERV2*    DSET1     DSET2     DSET3*    DTSTEP    PROP
SING     -  BOLT      DERV2*    DSET1     DSET2     DSET3*    DTSTEP    PROP
SIN2B    -  BOLT      DERV2*    DSET1     DSET2     DSET3*    DTSTEP    PROP
SIN2G    -  BOLT      DERV2*    DSET1     DSET2     DSET3*    DTSTEP    PROP
SL       -  BOLT*
```

```
SM       -  DERV2*
SMAX     -  DSET1     DSET2     DSET3     LIST1     LIST2     PROP*
SM2      -  DERV2*
SN       -  DERV2*
SN2      -  DERV2*
SOLVE    -  RELAXP*
SQRT     -  BOLT*     DSET2*    DISTEP*   LIST1*    PINIT*    SIGMA*
SQSIG    -  SIGMA*
SS1      -  DERV2*
SS10     -  DERV2*
SS11     -  DERV2*
SS12     -  DERV2*
SS13     -  DERV2*
SS14     -  DERV2*
SS15     -  DERV2*
SS16     -  DERV2*
SS2      -  DERV2*
SS3      -  DERV2*
SS4      -  DERV2*
SS5      -  DERV2*
SS6      -  DERV2*
SS7      -  DERV2*
SS8      -  DERV2*
SS9      -  DERV2*
STOP     -  DEPROP*
STT      -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROP      REIT*     SIGMA*
SU       -  DERV2*
SUM      -  REIT*
SUMRH    -  DSET2*
SUM1     -  REIT*
SURS     -  DERV2*
SV       -  DERV2*
SVRS     -  DERV2*
SW       -  DERV2*
SWRS     -  DERV2*
SXT      -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROP      REIT*     SIGMA*
SXX      -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROP      REIT*     SIGMA*
S1       -  DERV2*    LIST1*    LIST2*    SIGMA*
S1A      -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROP      REIT      SIGMA*
```

```
S11      -  DERV2*
S14      -  DERV2*
S2       -  DERV2*    LIST1*    LIST2*    SIGMA*
S2A      -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROP      REIT      SIGMA*
S3       -  DERV2*
S3A      -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROP      REIT      SIGMA*
S4       -  DERV2*
S4A      -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROP      REIT      SIGMA*
S5A      -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROP      REIT      SIGMA*
S6       -  DERV2*
S6A      -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2*    PINIT     PRESS
            PROP      REIT      SIGMA*
S7       -  DERV2*
S9       -  DERV2*
T        -  SOLVE*
TCRIT    -  DSET1     DSET2*    DSET3     LIST1     LIST2     PROP
TD       -  PRESS*
TF       -  PROP*
TH       -  LIST1*    LIST2*
THETAO   -  DSET1*    DSET2     DSET3*    DTSTEP*   PROP
THETR    -  DTSTEP*
THNU     -  DSET1*    DSET2*    DSET3*    LIST1*    LIST2     PROP
TIME     -  DEPROP    DERV2*    DSET1     DSET2     DSET3     DTSTEP    HIM*      LIST1*
            LIST2*    PINIT     PRESS*    PROP*     SIGMA*
TITLE    -  DEPROP*   DERV2     DSET1     DSET2     DSET3     DTSTEP    LIST1     LIST2
            PINIT     PRESS     PROP      SIGMA
TMAX     -  DSET1     DSET2     DSET3     LIST1     LIST2     PROP*
TNU      -  DSET1*    DSET2*    DSET3*    LIST2     PROP      REIT      SIGMA*
TNUSQ    -  DSET1     DSET2     DSET3     LIST2     PROP      REIT      SIGMA*
TOL      -  SIGMA*
TOTUB    -  DERV2*
TOTUM    -  DERV2*
TOTVB    -  DERV2*
TOTVM    -  DERV2*
TOTWB    -  DERV2*
TOTWM    -  DERV2*
TPRIME   -  DEPROP    PINIT*    PRESS*
TSTAR    -  PRESS*
```

```
TSTOP     -  DEPROP    DERV2     DSET1*    DSET2     DSET3*    DTSTEP    LIST1     LIST2
             PINIT     PRESS     PROP*     SIGMA
TT        -  DEPROP    PINIT*    PRESS*
TTNU      -  SIGMA*
TTO       -  DEPROP    PINIT*    PRESS*
TT1       -  PINIT*
T1        -  DERV2*    PRESS*    SIGMA*
T2        -  DERV2*    SIGMA*
T3        -  DERV2*    SIGMA*
T4        -  DERV2*
T5        -  DERV2*
U         -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PROP      REIT
UB        -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2     PROP      REIT
UBF       -  DERV2*
UF        -  DERV2*    LIST1*    LIST2*
UG        -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2     PROP      REIT
UGF       -  DERV2*
UMN       -  DERV2*
UU        -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PINIT     PRESS
             PROP      REIT      SIGMA
U1        -  DSET1     DSET2     DSET3     PROP*
V         -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PROP      REIT
VB        -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2     PROP      REIT
VBF       -  DERV2*
VF        -  DERV2*    LIST1*    LIST2*
VG        -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2     PROP      REIT
VGF       -  DERV2*
VMN       -  DERV2*
VRT       -  DERV2     DSET1     DSET3     LIST1*    LIST2*    PROP      REIT*
VRX       -  DERV2     DSET1     DSET3     LIST1*    LIST2*    PROP      REIT*
VS        -  DEPROP    PINIT*    PRESS*
VV        -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PINIT     PRESS
             PROP      REIT      SIGMA
VXO       -  DERV2     DSET1     DSET2     DSET3     HIM*      PROP*     SIGMA
V1        -  DSET1     DSET2     DSET3     PROP*
W         -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PROP      REIT
WB        -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2     PROP      REIT
WBB       -  DERV2*    DSET1     DSET2     DSET3     LIST1     LIST2     PROP      REIT
WBBB      -  DERV2*    DSET1     DSET3     LIST1     LIST2     PROP      REIT*
WBBF      -  DERV2*
WBF       -  DERV2*
WF        -  DERV2*    LIST1*    LIST2*
```

```
WG      -  DERV2*   DSET1    DSET2    DSET3    LIST1    LIST2    PROP     REIT
WGB     -  DERV2*   DSET1    DSET2    DSET3    LIST1    LIST2    PROP     REIT*
WGBB    -  DERV2*   DSET1    DSET3    LIST1    LIST2    PROP     REIT*
WGBF    -  DERV2*
WGF     -  DERV2*
WGG     -  DERV2*   DSET1    DSET2    DSET3    LIST1    LIST2    PROP     REIT
WGGB    -  DERV2*   DSET1    DSET3    LIST1    LIST2    PROP     REIT*
WGGF    -  DERV2*
WGGG    -  DERV2*   DSET1    DSET3    LIST1    LIST2    PROP     REIT*
WMN     -  DERV2*
WW      -  DERV2*   DSET1    DSET2    DSET3    LIST1*   LIST2*   PINIT    PRESS
           PROF     REIT     SIGMA
W1      -  DSET1    DSET2    DSET3    PROF*
X       -  HIM*     LIST1*   LIST2*   PINIT*   RELAXP*
XR      -  DERV2    DSET1    DSET2    DSET3*   LIST1*   LIST2*   PINIT*   PRESS
           PROF     REIT     SIGMA
XG      -  DERV2    DSET1    DSET2    DSET3*   LIST1*   LIST2*   PINIT*   PRESS
           PROP     REIT     SIGMA
XJ      -  BOLT     DERV2*   DSET1*   DSET2    DSET3*   DTSTEP   PROP
XJ2     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
XJ3     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
XJ4     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
XJ5     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
XKIT    -  DERV2*   DSET1    DSET2    DSET3    LIST1*   LIST2*   PINIT    PRESS
           PROF     REIT     SIGMA*
XKXT    -  DERV2*   DSET1    DSET2    DSET3    LIST1*   LIST2*   PINIT    PRESS
           PROF     REIT     SIGMA*
XKXX    -  DERV2*   DSET1    DSET2    DSET3    LIST1*   LIST2*   PINIT    PRESS
           PROF     REIT     SIGMA*
XL      -  BOLT     DERV2    DSET1    DSET2    DSET3*   DTSTEP   PROP
XLP     -  BOLT     DERV2    DSET1*   DSET2    DSET3*   DTSTEP*  PROP
XLP1    -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
XLP2    -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
XL1     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
XL2     -  BOLT     DERV2    DSET1    DSET2    DSET3*   DTSTEP   PROP
XL3     -  BOLT     DERV2*   DSET1    DSET2    DSET3*   DTSTEP   PROP
XL4     -  BOLT     DERV2    DSET1    DSET2    DSET3*   DTSTEP   PROP
XL5     -  BOLT     DERV2    DSET1    DSET2    DSET3*   DTSTEP   PROP
```

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XL7     -  BOLT      DERV2*    DSET1     DSET2     DSET3*    DTSTEP    PROP
XNUB    -  DSET2*
XO      -  PINIT*
XP      -  DEPROP    PINIT*    PRESS
XPROP   -  RELAXP*
XRES    -  RELAXP*
XX      -  DERV2*    DSET1     DSET2     DSET3     PROF*     SIGMA
XXNU    -  DSET1*    DSET2*    DSET3*    LIST1*    LIST2     PROP
XX1     -  RELAXP*
X1      -  BOLT*     DSET3*    LIST1*    LIST2*
X1A     -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PINIT     PRESS
           PROP      REIT      SIGMA*
X2      -  BOLT*     LIST1*    LIST2*
X2A     -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PINIT     PRESS
           PROF      REIT      SIGMA*
X3      -  BOLT*     HIM*      LIST1*    LIST2*
X3A     -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PINIT     PRESS
           PROF      REIT      SIGMA*
X4      -  HIM*
X4A     -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PINIT     PRESS
           PFOP      REIT      SIGMA*
X5A     -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PINIT     PRESS
           PROP      REIT      SIGMA*
X6A     -  DERV2*    DSET1     DSET2     DSET3     LIST1*    LIST2*    PINIT     PRESS
           PROP      REIT      SIGMA*
Y       -  LIST1*    LIST2*    PINIT*
YO      -  PINIT*
YP      -  DEPROP    PINIT*    PRESS
YY      -  DERV2*    DSET1     DSET2     DSET3     PROP*     SIGMA
ZA      -  DERV2     DSET1     DSET2     DSET3*    LIST1     LIST2*    PINIT     PRESS
           PROF      REIT      SIGMA
ZB      -  DERV2     DSET1     DSET2*    DSET3*    LIST1     LIST2*    PINIT     PRESS
           PROP      REIT      SIGMA
ZC      -  DSET1     DSET2*    DSET3     LIST1*    LIST2     PROP
ZEF     -  DEPROP    PINIT*    PRESS*
ZE      -  DERV2     DSET1     DSET2     DSET3*    LIST1     LIST2*    PINIT     PRESS
           PROF      REIT      SIGMA*
ZG      -  DERV2     DSET1     DSET2     DSET3*    LIST1     LIST2     PINIT     PRESS
           FROF      REIT      SIGMA
ZH      -  DERV2     DSET1     DSET2     DSET3*    LIST1     LIST2     PINIT     PRESS
           PROP      REIT      SIGMA
```

```
ZZ        - PRESS*
ZZ1       - DEPROF    DERV2     CSET1     DSET2     DSET3     DTSTEP    LIST1     LIST2
            PINIT     PRESS     PRCP      SIGMA

THE FOLLOWING  10 SYMBOLS ARE NOT USED IN ANY OF THE ROUTINES LISTED ABOVE -

            CINST     CZ        GAMMA     KALT      NCHET     NMASS     RP        ROAM
            RFR       ZZ1

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APPENDIX B

PROGRAM LISTING

```
*COMDECK FIRST
      COMMON /FIRST/ ICOUNT
*COMDECK CNOVA
      COMMON/CNOVA/  CRIT(5),DELTIM,GAMMA(41),ICOMP,INOUT,KALT,KB,
     1   KDAM,KDS,KERR,KOK,KTYPE,NCALL,NCASE,NCHPT,NDBUG,NMASS,NTRIAL,
     2  PB(40),PDAM,PPP,PRINT,RFR,RTRIAL(5),TIME,TITLE(20),TSTOP,
     3   ZZ1(9)
*COMDECK CLOAD
      COMMON /CLOAD/ PP1,PPO,ITO,TPRIME,AA,ANN,DTT1,OTTO,AZ,
     1  JL,NTIME,NLOAD,PT(20),TT(20), ZEE,PHI,Q1,Q2,VS,
     2  DET(10,10),NPX,NPY,DTIM,PRT(6,10,10),XP(10),YP(10),
     3  IXI(23),JYJ(23),JLT(10,10),PRTT(10,10),DX1(23),DY1(23)
*COMDECK CBLK1
      COMMON/CBLK1/  A,KZ,LBAR,LMAX,MB,MBAR,MG,MGM(13),MGMB,MGMB2,
     1   NBAR,NBN(13),NBND,NBT,NDERV,NGNB,NGT,NPLT,NSYMB,NSYMG,PI
     2   ,MUSE(13,13),NB,NG,NGNBT
*COMDECK CBLK2
      COMMON/CBLK2/  BETR(23),CC1(13),CC2(13),CC5(13),CC6(13),
     1   CK(6),COSB(299),COSG(299),COS2B(299),COS2G(299),DPRT,DPRT1,
     2   FP1(299),FP2(299),FP3(299),FP4(13,2),FP5(299),FP6(299),
     3   FP7(299),FP8(13,2),
     3   GAM(23),KC,PIMA(23),PINA(23),SINB(299),SING(299),
     4   SIN2B(299),SIN2G(299),XJ,XJ2,XJ3,XJ4,XJ5,XL,XLP,XLP1,XLP2,
     5   XL0,XL2,XL3,XL4,XL5,XL7
*COMDECK CBLK3
      COMMON/CBLK3/  GX(6),HGO(6)
*COMDECK CBLK4
      COMMON/CBLK4/  NY2,VXO(147),XX(147),YY(147)
*COMDECK CBLK5
      COMMON/CBLK5/  EM(8),ERR(147),FG(13,13),HM(8),MOUT(169),
     1   NOUT(169),RMOM(8),U1(13,13),V1(13,13),W1(13,13)
*COMDECK CBLK6
      COMMON  /CBLK6/  ALTT(1805),
     1   ALXT(1805),ALXX(1805),BE1(1805),BE2(1805),BE3(1805),
     2   EP8(1805),ETT1(1805),
     3   EXT1(1805),EXX1(1805),SIGTT1(1805),SIGXT1(1805),SIGXX1(1805),
     4   TTNU(1805)
*COMDECK CBLK7
      COMMON/CBLK7/  CN1,CN12,CN13,CN2,CN3,CN4,CN5,CN6,CN7,EL,EP,
     1   EPO,EPP,H,IFIRST,JFIRST,LC,LCMAX,NELP,SIGO,SIGO2,TNU,TNUSU
```

```
*COMDECK CBLK8
      COMMON/CBLK8/  NU,P(361),WA(23,23)
*COMDECK CBLK9
      COMMON/CBLK9/  BTL(8),BXL(8),CCRIT(8),CINST(3),ET(8),
     1   EX(8),GXI(8),NLZ(16),NREG,NTECO,NZP,SAC(8),SAT(8),SMAX,
     2   TCRIT(8),THNU(8),TMAX,XXNU(8),ZC(16)
*COMDECK CBLK10
      COMMON/CBLK10/ DWB(361),DWG(361),DWD(361),        U(361),
     1   UB(361),UG(361),V(361),VB(361),VG(361),W(361),WB(361),
     2   WBB(361),WG(361),WGB(361),WGG(361)
*COMDECK CBLK11
      COMMON/CBLK11/ CM11,CM12,CM22,CM33,DM11,DM12,DM22,DM33,FM11,
     1   FM12,FM22,FM33
*COMDECK CBLK12
      COMMON /CBLK12/ DELX(147),IP(147),PRES(147),PX(147),RREG(147),
     1   SIGX(147),XRES(147,147),XX1(147)
*COMDECK CBLK13
      COMMON/CBLK13/ DC,EC,EPSIF,GC,HBAR,NL,NNOUT,RHO,THETA0
*COMDECK CBLK14
      COMMON /CBLK14/ NBUSE(23,23),NRC,C1,C2,C3,C4,C5,C6,C7,
     1  DELX,DELT,    WGGG(44),WBBB(44),WGGB(44),WGBB(44),
     2  VRX(44),VRT(44),RR(4),ENX(44),ENT(44),NKP,KPG(46),KPB(46)
*COMDECK CBLANK
      COMMON           CN10,CN11,CN8,CN9,EPBO(1805),ETT,EXT,EXX,
     1   INZ(2),KSUMA(361),KY(1805),NUSE(23,23),
     2   STT(1805),SXT(1805),
     3   SXX(1805),UU(13,13),VV(13,13),WW(13,13),XB(23),XG(23),XKTT,
     4   XKXT,XKXX,X1A(361),X2A(361),X3A(361),X4A(361),X5A(361),
     5   X6A(361),ZA(2),ZB(2),ZF(6),ZG(6),ZH(6), S1A(361),S2A(361),
     6   S3A(361),S4A(361),S5A(361),S6A(361)
```

```
*DECK DEPROP
      PROGRAM DEPROP (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
*CALL FIRST
*CALL CNOVA
*CALL CLOAD
C
    1 FORMAT(6I12)
    2 FORMAT(6F12.1)
    3 FORMAT (20A4)
      NCASE = 0
      INOUT = 1
      ICOMP = 5
      ICOUNT = 37777000000000000000B
      READ(5,1) NCASES
  100 READ (5,3) (TITLE(I),I=1,20)
      NCASE = NCASE + 1
      KERR = 0
      NTRIAL = 0
      KDAM = 2
      READ (5,1) KTYPE,KDS,NDBUG
      IF(INOUT.EQ.0) GO TO 1400
      WRITE(6,3000) (TITLE(I),I=1,20)
      GO TO (300,400,500,600,700), KTYPE
  300 WRITE(6,3500)
      GO TO 1050
  400 WRITE(6,3600)
      GO TO 1050
  500 WRITE(6,3700)
      GO TO 1050
  600 WRITE(6,3800)
      GO TO 1050
  700 WRITE(6,3900)
      GO TO 1050
 1050 GO TO (1100,1200,1300), KDS
 1100 WRITE(6,4300)
      GO TO 1400
 1200 WRITE(6,4400)
      GO TO 1400
 1300 WRITE(6,4500)
 1400 NCALL = 2
```

```
      CALL PROP
      IF(KERR.GT.0) GO TO 1600
      NCALL = 1
      CALL PINIT(0)
      CALL PROP
      IF(KOS.EQ.1) GO TO 1600
      IF(KERR.GT.0) GO TO 1600
      NCALL = 0
      KOK = 0
      CALL PINIT(1)
      RTRIAL(1)=1.0
 1500 NTRIAL = NTRIAL + 1
      CALL PROP
 1600 IF(NCASE.LT.NCASES) GO TO 100
 1700 STOP
C
 3000 FORMAT (1H1,30X,11HD E P R O P//1X,20A4)
 3500 FORMAT (28H0SINGLE-LAYER METAL PANEL   )
 3600 FORMAT (30H0SINGLE-LAYER PLASTIC PANEL   )
 3700 FORMAT (25H0HONEYCOMB METAL PANEL   )
 3800 FORMAT (27H0HONEYCOMB PLASTIC PANEL   )
 3900 FORMAT (29H0MULTI-LAYER PLASTIC PANEL   )
 4300 FORMAT (21H0STATIC SOLUTION ONLY)
 4400 FORMAT (22H0DYNAMIC RESPONSE ONLY)
 4500 FORMAT (37H0STATIC SOLUTION AND DYNAMIC RESPONSE)
      END
```

```
*DECK BOLT
      SUBROUTINE BOLT
C
C     THIS SUBROUTINE SETS UP W MODE SHAPES FOR BOUNDARY CONDITIONS
C       SELECTED.
C
*CALL CBLK1
*CALL CBLK2
      DIMENSION CD1(20),CD2(20),CD3(20),CD4(20)
      DIMENSION CDL(20), CDA(20)
      DATA CD1/1.5056187314,2.49975267005,3.50001067945,4.49999953847,
     1  5.50000001994,6.49999999915,7.5,8.5,9.5,10.5,11.5,12.5,13.5,
     2  14.5,15.5,16.5,17.5,18.5,19.5,20.5/
      DATA CD2/0.982502214568,1.00077731189,0.999966450124,
     1  1.00000144989,0.999999937336,1.00000000270,0.999999999881,
     2  13*1.0/
      DATA CD3/1.24987633505,2.24999976925,3.24999999959,4.25,5.25,6.25,
     1  7.25,8.25,9.25,10.25,11.25,12.25,13.25,14.25,15.25,16.25,
     2  17.25,18.25,19.25,20.25/
      DATA CD4/1.00077731192,1.00000144989,1.00000000269,17*1.0/
C
C
      FAC = SQRT(2.0)
      DO 100 I=1,4
  100 CK(I) = FAC
      II = 0
      GO TO (500,700,500,700,900,500,900,700,900), NBND
C
C     CLAMPED - CLAMPED, GAMMA.
C
  500 DO 520 I=1,MG
      M = MGM(I)
      CDL(I) = CD1(M)
  520 CDA(I) = CD2(M)
  540 DO 600  M=1,MG
      X1 = CDL(M)
      X2 = CDA(M)
      DO 600 I=1,NGT
      II = II + 1
      X3 = X1*GAM(I)
      EX1 = EXP(X3)
      EX2 = EXP(-X3)
      SL = SIN(X3)
      CL = COS(X3)
      FP1(II) = -CL + X2*SL + .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1
      FP2(II) = X1*(SL + X2*CL - .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1)
      FP3(II) = X1**2*(CL - X2*SL + .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1)
      IF (I.EQ.1) FP4( M,1) = -2.0*X2*X1**3
      IF (I.EQ.MBAR) FP4( M,2) = X1**3*(-SL - X2*CL + .5*((1. - X2)*
     1  EX1 - (1. + X2)*EX2))
  600 CONTINUE
      CK(5) = 1./FAC
      GO TO 1000
C
C     SIMPLY - SIMPLY, GAMMA.
C
  700 DO 800 M=1,MG
      X1 = MGM(M)
      DO 800 I=1,NGT
      II = II + 1
      X2 = X1*GAM(I)
      X3 = SIN(X2)
      FP1(II) = X3
      FP2(II) = X1*COS(X2)
      FP3(II) = -X1**2*X3
      IF (I.EQ.1) FP4(M,1) = -X1**3
      IF (I.EQ.MBAR) FP4(M,2) = -X1**3*COS(X2)
  800 CONTINUE
      CK(5) = FAC
      GO TO 1000
C
C     CLAMPED - SIMPLY, GAMMA.
  900 DO 920 I=1,MG
      M = MGM(I)
      CDL(I) = CD3(M)
  920 CDA(I) = CD4(M)
      GO TO 540
C
C
 1000 II = 0
```

BOLT

```
      GO TO (1100,1300,1300,1100,1100,1500,1300,1500,1500), NBND
C
C     CLAMPED - CLAMPED, BETA.
C
 1100 DO 1120 I=1,MB
      N = NBN(I)
      CDL(I) = CD1(N)
 1120 CDA(I) = CD2(N)
 1140 DO 1200  N=1,MB
      X1 = CDL(N)
      X2 = CDA(N)
      DO 1200 J=1,NBT
      II = II + 1
      X3 = X1*BETR(J)
      EX1 = EXP(X3)
      EX2 = EXP(-X3)
      SL = SIN(X3)
      CL = COS(X3)
      FP5(II) = -CL + X2*SL + .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1
      FP6(II) = X1*(SL + X2*CL - .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1)
      FP7(II) = X1**2*(CL - X2*SL + .5*(1.+X2)*EX2 + .5*(1.-X2)*EX1)
      IF (J.EQ.1) FP8( N,1) = -2.0*X2*X1**3
      IF (J.EQ.NBAR) FP8( N,2) = X1**3*(-SL - X2*CL + .5*((1. - X2)*
     1  EX1 - (1. + X2)*EX2))
 1200 CONTINUE
      CK(6) = 1./FAC
      GO TO 1600
C
C     SIMPLY - SIMPLY, BETA.
C
 1300 DO 1400 N=1,MB
      X1 = NBN(N)
      DO 1400 J=1,NBT
      II = II + 1
      X2 = X1*BETR(J)
      X3 = SIN(X2)
      FP5(II) = X3
      FP6(II) = X1*COS(X2)
      FP7(II) = -X1**2*X3
      IF (J.EQ.1) FP8(N,1) = -X1**3
      IF (J.EQ.NBAR) FP8(N,2) = -X1**3*COS(X2)
 1400 CONTINUE
      CK(6) = FAC
      GO TO 1600
C
C     CLAMPED - SIMPLE, BETA.
 1500 DO 1520 I=1,MB
      N = NBN(I)
      CDL(I) = CD3(N)
 1520 CDA(I) = CD4(N)
      GO TO 1140
C
 1600 RETURN
      END
```

```
*DECK DERV2
      SUBROUTINE DERV2
C
*CALL CBLK1
*CALL CBLK2
*CALL CBLK3
*CALL CBLK4
*CALL CBLK8
*CALL CBLK10
*CALL CBLK11
*CALL CBLK14
*CALL CNOVA
*CALL CBLANK
C
      IF(NCALL.EQ.0) CALL PRESS
C
      I=1
      DO 100 M=1,MG
      DO 100 N=1,MB
      IF(MUSE(N,M).EQ.0) GO TO 100
      UU(N,M)=XX(I)
      VV(N,M)=XX(MGMB+I)
      WW(N,M)= XX(MGMB2+I)
      I=I+1
  100 CONTINUE
      K=0
      DO 500 I=1,NGT
      II = 0
      IF (I.EQ.1) II = 1
      IF (I.EQ.MBAR.AND.NSYMG.EQ.1) II = 2
      DO 500 J=1,NBT
      IF(NUSE(J,I).EQ.0) GO TO 500
      NBC = NBUSE(J,I)
      JJ = 0
      IF (J.EQ.1) JJ = 1
      IF (J.EQ.NBAR.AND.NSYMB.EQ.1) JJ = 2
      K=K+1
      SS1=0.0
      SS2=0.0
      SS3=0.0
```

```
SS4=0.0
SS5=0.0
SS6=0.0
SS7=0.0
SS8=0.0
SS9=0.0
SS10=0.0
SS11=0.0
SS12=0.0
SS13 = 0.
SS14 = 0.
SS15 = 0.
SS16 = 0.
DO 400 M=1,MG
MM= (M-1)*NGT+I
SM=SING(MM)
CM=COSG(MM)
SM2=SIN2G(MM)
CM2=COS2G(MM)
T1 = FP1(MM)
T2 = FP2(MM)
T3 = FP3(MM)
T4 = 0.
IF (II.GT.0) T4 = FP4(M,II)
S1=0.0
S3=0.0
S4=0.0
S6=0.0
S7=0.0
S9=0.0
S11=0.0
S14 = 0.
DO 200 N=1,MB
IF(MUSE(N,M).EQ.0) GO TO 200
NN= (N-1)*NBT+J
T5 = 0.
IF (JJ.GT.0) T5 = FP8(N,JJ)
SN=SINB(NN)
CN=COSB(NN)
SN2=SIN2B(NN)
```

```
      CN2=COS2B(NN)
      UMN=UU(N,M)
      VMN=VV(N,M)
      WMN=WW(N,M)
      S1=S1+UMN*SN2
      S3=S3+CC2(N)*UMN*CN2
      S4=S4+VMN*SN
      S6=S6+CC6(N)*VMN*CN
      S7 = WMN*FP5(NN) + S7
      S9 = WMN*FP6(NN) + S9
      S11 = WMN*FP7(NN) + S11
      S14 = WMN*T5 + S14
200   CONTINUE
      SS1=S1*SM+SS1
      SS2=S1*CC5(M)*CM + SS2
      SS3=S3*SM + SS3
      SS4=S4*SM2+SS4
      SS5=S4*CC1(M)*CM2+SS5
      SS6=S6*SM2+SS6
      SS7 = S7*T1 + SS7
      SS8 = S7*T2 + SS8
      SS9 = S9*T1 + SS9
      SS10 = S7*T3 + SS10
      SS11 = S11*T1 + SS11
      SS12 = S9*T2 + SS12
      IF (NBC.EQ.0.OR.NBC.GT.100) GO TO 400
      SS13 = S7*T4 + SS13
      SS14 = S14*T1 + SS14
      SS15 = S11*T2 + SS15
      SS16 = S9*T3 + SS16
400   CONTINUE
      U(K)=SS1
      UG(K)=SS2
      UB(K)=SS3
      V(K)=SS4
      VG(K)=SS5
      VB(K)=SS6
      W(K)=SS7
      WG(K)=SS8
      WB(K)=SS9
      WGG(K)=SS10
      WBB(K)=SS11
      WGB(K)=SS12
      IF (NBC.EQ.0.OR.NBC.GT.100) GO TO 500
      NBC = IABS(NBC)
      IF (II.EQ.0) GO TO 450
      WGGG(NBC) = SS13
      WGBB(NBC) = SS15
      GO TO 500
  450 WBBB(NBC) = SS14
      WGGB(NBC) = SS16
  500 CONTINUE
C
C   COMPUTE STRAINS AND STRESSES
C
      K=0
      DO 700 I=1,NGT
      DO 700 J=1,NBT
      IF(NUSE(J,I).EQ.0) GO TO 700
      K=K+1
      UF=U(K)
      UGF=UG(K)
      UBF=UB(K)
      VF=V(K)
      VGF=VG(K)
      VBF=VB(K)
      WF=W(K)
      WGF=WG(K)
      WBF=WB(K)
      DWGF=DWG(K)
      DWBF=DWB(K)
      EXX=XL1*(UGF+XL1*(WGF*DWGF+0.5*(WGF**2+VGF**2+UGF**2)))
      ETT=XJ*(VBF+XJ*(WBF*DWBF+0.5*(WBF**2+VBF**2+UBF**2)))
      EXT=XJ*UBF+XL1*(VGF*(1.0+XJ*VBF)+XJ*(WGF*(WBF+DWBF)+DWGF*WBF+UBF*
     1UGF))
      AC = XJ*VBF + XL1*UGF + 1.0
      WGGF = WGB(K)
      WBBF = WBB(K)
      WGBF = WGB(K)
      XKXX = XL7*WGGF*AC
```

DERV2

```
      XKTT = XJ2*WBBF*AC
      XKXT = XJ5*WGBF*AC
      IF(NPLT.EQ.0) GO TO 600
      ETT=ETT-WF*(1.0+XJ*VBF-0.5*WF)+VF*(XJ*WBF+0.5*VF)
      EXT =EXT+XL1*(WGF*VF-VGF*WF)
      XKTT=XKTT+XJ4*VBF+XL1*UGF-WF
      XKXT=XKXT+XL1*VGF
      AC = XJ*WBF + VF
      XKXX = XKXX - XL7*WGGF*WF
      XKTT = XKTT + XJ*VBF*(XJ*VBF - WF) - XJ2*WF*WBBF +
     1  (XJ*VBF - WF)**2 + AC*(AC + XJ*WBF)
      XKXT = XKXT - XJ5*WGBF*WF + XL3*WGF*AC
  600 IF (NDERV.EQ.2) GO TO 640
      S1A(K) = CM11*EXX + CM12*ETT + FM11*XKXX + FM12*XKTT
      S2A(K) = CM22*ETT + CM12*EXX + FM22*XKTT + FM12*XKXX
      S3A(K) = CM33*EXT + FM33*XKXT
      S4A(K)  = DM11*XKXX + DM12*XKTT + FM11*EXX + FM12*ETT
      S5A(K)  = DM22*XKTT + DM12*XKXX + FM22*ETT + FM12*EXX
      S6A(K)  = DM33*XKXT + FM33*EXT
      GO TO 660
  640 CALL SIGMA (J,I,K)
  660 X1A(K) = EXX
      X2A(K) = ETT
      X3A(K) = EXT
      X4A(K) = XKXX
      X5A(K) = XKTT
      X6A(K) = XKXT
 700  CONTINUE
      IF(KERR.GT.0) GO TO 2200
C
      K = 0
      DO 750 I=1,NGT
      DO 750 J=1,NBT
      IF (NUSE(J,I).GT.0) K = K + 1
      IF (NBUSE(J,I).NE.0) CALL REIT(I,J,K)
  750 CONTINUE
C
      IF(NCALL.EQ.1) GO TO 900
      KZ=0
      IF (KDAM.LT.2.AND.KC.EQ.10) KZ = 1
      IF (PRINT.EQ.0.) GO TO 800
      IF(TIME.LT.DPRT) GO TO 800
      KZ=KZ+2
      IF (KDAM.LT.2) KZ = 3
      DPRT=DPRT+DPRT1
C     PRINT RESULTS AND/OR CHECK MAXIMUMS
  800 IF (NDERV.EQ.1) CALL LIST1
      IF (NDERV.EQ.2) CALL LIST2
      IF (KZ.EQ.1.OR.KZ.EQ.3) KC = 0
      KC = KC + 1
C
C
 900  IZ=0
      DO 1800 IR=1,MG
      MMO=(IR-1)*NGT
      DO 1800 IS=1,MB
      IF(MUSE(IS,IR).EQ.0) GO TO 1800
      NNO=(IS-1)*NBT
      IZ=IZ+1
      SURS=0.0
      SVRS=0.0
      SWRS=0.0
      K=0
      DO 1700 I=1,NGT
      MM=MMO+I
      SM=SING(MM)
      CM=COSG(MM)
      SM2=SIN2G(MM)
      CM2=COS2G(MM)
      T1 = FP1(MM)
      T2 = FP2(MM)
      T3 = FP3(MM)
      SU = 0.
      SV = 0.
      SW = 0.
      PRLM = PIMA(I)
      DO 1600 J=1,NBT
      IF (NUSE(J,I).EQ.0) GO TO 1600
      K = K + 1
      IF (NUSE(J,I).EQ.1) GO TO 1600
      PRLN = PINA(J)
      NN=NNO+J
      SN=SINB(NN)
      CN=COSB(NN)
      SN2=SIN2B(NN)
      CN2=COS2B(NN)
      UF=U(K)
      UGF=UG(K)
      UBF=UB(K)
      VF=V(K)
      VGF=VG(K)
      VBF=VB(K)
      WF=W(K)
      WGF=WG(K)
      WBF=WB(K)
      WGGF = WGG(K)
      WBBF = WBB(K)
      WGBF = WGB(K)
      DWGF=DWG(K)
      DWBF=DWB(K)
      IF(NU.EQ.0) PPP=P(K)
      PU=SM*SN2
      PUG=CC5(IR)*CM*SN2
      PUB=CC8(IS)*SM*CN2
      PV=SM2*SN
      PVG=CC1(IR)*CM2*SN
      PVB=CC6(IS)*SM2*CN
      PW = T1*FP5(NN)
      PWG = T2*FP5(NN)
      PWB = T1*FP6(NN)
      PWGG = T3*FP5(NN)
      PWBB = T1*FP7(NN)
      PWGB = T2*FP6(NN)
 1100 PEXXU=XL1*PUG*(1.0+XL1*UGF)
      PEXXV=XL7*VGF*PVG
      PEXXW=XL7*PWG*(WGF+DWGF)
      PETTU=XJ2*UBF*PUB
      PETTV = XJ*PVB*(1.0 + XJ*VBF)
      PETTW = XJ2*PWB*(WBF + DWBF)
      PEXTU=XJ*(PUB*(1.0+XL1*UGF)+XL1*UBF*PUG)
      PEXTV = XL1*(PVG*(1.0 + XJ*VBF) + XJ*VGF*PVB)
      PEXTW = XJ3*(PWB*(WGF+DWGF) + PWG*(WBF+DWBF))
      PKXXW=XL7*PWGG
      PKTTW=XJ2*PWBB
      PKXTW=XJ5*PWGB
      AC = XJ*VBF + XL1*UGF
      PKXXU = XL1*XL7*WGGF*PUG
      PKXXV = XJ*XL7*WGGF*PVB
      PKXXW = PKXXW + XL7*PWGG*AC
      PKTTU = XJ2*XL1*WBBF*PUG
      PKTTV = PVB*XJ*XJ2*WBBF
      PKTTW = PKTTW + PWBB*XJ2*AC
      PKXTU = XJ4*XL7*WGBF*PUG
      PKXTV = XL3*XJ2*WGBF*PVB
      PKXTW = PKXTW + XJ5*PWGB*AC
      S1=0.0
      S2=0.0
      IF(NPLT.EQ.0) GO TO 1200
      PETTV=PETTV+PV*(VF+XJ*WBF) - XJ*WF*PVB
      PETTW=PETTW - PW*(1.0+XJ*VBF-WF) + XJ*VF*PWB
      PEXTV=PEXTV + XL1*(WGF*PV-WF*PVG)
      PEXTW=PEXTW + XL1*(VF*PWG-VGF*PW)
      PKTTU = XL1*PUG + PKTTU
      PKTTV=XJ4*PVB + PKTTV
      PKTTW=PKTTW - PW
      PKXTV=XL1*PVG + PKXTV
      PKXXW = PKXXW - XL7*(PWGG*WF + PW*WGGF)
      PKTTV = PKTTV + XJ*PVB*(4.*XJ*VBF - 3.*WF) +
     1  PV*(3.*XJ*WBF + 2.*VF)
      PKTTW = PKTTW + XJ2*PWBB*(-WF + XL1*UGF) + PW*(2.*WF -
     1  3.*XJ*VBF - XJ2*WBBF) + PWB*XJ*(4.*XJ*WBF + 3.*VF)
      PKXTV = PKXTV + XL3*PV*WGF
      PKXTW = PKXTW - XJ5*(PWGB*WF + PW*WGBF - PWB*WGF) +
     1  PWG*XL3*(XJ*WBF + VF)
      S1 = DWO(K) + WF
      S2 = VF
 1200 PU = XLP2*PPP*PU*(WGF + DWGF)
      PV = XLP1*PPP*PV*(XJ*(WBF + DWBF) + S2)
      PW = XLP1*PPP*PW*(S1 - XL1*UGF - XJ*VBF - 1.0)
      IF (NDERV.EQ.1) GO TO 1280
      J1 = LBAR*(K-1)
      KSUM = KSUMA(K)
      IF(KSUM.LT.LBAR) GO TO 1300
 1280 G1 = S1A(K)
      G2 = S2A(K)
      G3 = S3A(K)
      G4 = S4A(K)
      G5 = S5A(K)
      G6 = S6A(K)
      F1 = PEXXU*G1 + PETTU*G2 + PEXTU*G3
      F2 = PKXXU*G4 + PKTTU*G5 + PKXTU*G6
      F3 = PEXXV*G1 + PETTV*G2 + PEXTV*G3
      F4 = PKXXV*G4 + PKTTV*G5 + PKXTV*G6
      F5 = PEXXW*G1 + PETTW*G2 + PEXTW*G3
      F6 = PKXXW*G4 + PKTTW*G5 + PKXTW*G6
      FU = CN10*F1 + CN11*F2
      FV = CN10*F3 + CN11*F4
      FW = CN10*F5 + CN11*F6
      GO TO 1500
C
 1300 TOTUM=0.0
      TOTVM=0.0
      TOTWM = 0.0
      TOTUB = 0.0
      TOTVB = 0.0
      TOTWB = 0.0
      DO 1400 KK=1,LBAR
      L = JI + KK
      S1 = HGO(KK)
      S2 = GX(KK)*S1
      G1 = SXX(L)
      G2 = STT(L)
      G3 = SXT(L)
      TOTUM = TOTUM + S1*(PEXXU*G1 + PETTU*G2 + PEXTU*G3)
      TOTUB = TOTUB + S2*(PKXXU*G1 + PKTTU*G2 + PKXTU*G3)
      TOTVM = TOTVM + S1*(PEXXV*G1 + PETTV*G2 + PEXTV*G3)
      TOTVB = TOTVB + S2*(PKXXV*G1 + PKTTV*G2 + PKXTV*G3)
      TOTWM = TOTWM + S1*(PEXXW*G1 + PETTW*G2 + PEXTW*G3)
 1400 TOTWB=TOTWB+S2*(PKXXW*G1 +PKTTW*G2 +PKXTW*G3)
      FU = CN8*TOTUM + CN9*TOTUB
      FV = CN8*TOTVM + CN9*TOTVB
      FW = CN8*TOTWM + CN9*TOTWB
C
 1500 SU = SU + (FU + PU)*PRLN
      SV = SV + (FV + PV)*PRLN
      SW = SW + (FW + PW)*PRLN
 1600 CONTINUE
      SURS = SURS + PRLM*SU
      SVRS = SVRS + PRLM*SV
      SWRS = SWRS + PRLM*SW
 1700 CONTINUE
      IF (ABS(SWRS).GT.1.0E30) GO TO 2150
      YY(IZ) = -SURS*CK(1)*CK(2)
      YY(MGMB+IZ) = -SVRS*CK(3)*CK(4)
      YY(MGMB2+IZ) = -SWRS*CK(5)*CK(6)
 1800 CONTINUE
      GO TO 2200
C
 2150 KERR = 1
      WRITE (6,2151)
 2151 FORMAT (30H0SOLUTION DIVERGING IN DEPROP )
C
 2200 RETURN
      END
```

```
*DECK DSET1
      SUBROUTINE DSET1
C
*CALL CBLK1
*CALL CBLK2
*CALL CBLK3
*CALL CBLK4
*CALL CBLK5
*CALL CBLK7
*CALL CBLK8
*CALL CBLK9
*CALL CBLK10
*CALL CBLK11
*CALL CBLK13
*CALL CBLK14
*CALL CNOVA
*CALL CBLANK
C
C   INPUT DATA
C
      READ(5,7000) MG,MB,MBAR,NBAR,LBAR
      READ (5,7000) (MGM(I),I=1,MG)
      READ (5,7000) (NBN(I),I=1,MB)
      READ (5,7000) NBYMB,NSYMB
      READ(5,7000) NPLT,NBND,NDERV
      READ(5,7000) NNOUT
      IF(NNOUT.EQ.0) GO TO 70
      DO 50 I=1,NNOUT
 50   READ(5,7000) MOUT(I),NOUT(I)
   70 READ(5,7000) NKP
      IF (NKP.EQ.0) GO TO 90
      DO 80 I=1,NKP
   80 READ(5,7000) KPG(I),KPB(I)
   90 IF(KDAM.EQ.1.AND.KTYPE.EQ.1) NDERV=2
      IF (KDAM.EQ.1.AND.KTYPE.EQ.3) NDERV = 2
      IF (NDERV.EQ.1) LBAR = 1
      READ (5,7000) NL
      IF (KTYPE.LT.5) NL = 3
      IF (KTYPE.LT.3) NL = 1
      READ(5,7100) XLP,THETA0,A
      IF(NPLT.EQ.0) A=1.0
      IF (NDERV.EQ.1) GO TO 150
      DO 100 I=1,NL
 100  READ(5,7100) HM(I),RHOM(I),EM(I)
      READ (5,7100) TNU,SIGO,EP,EPSIF
      GO TO 190
  150 DO 160 I=1,NL
      READ (5,7100) HM(I),RHOM(I)
      READ (5,7100) EX(I),ET(I),XXNU(I),THNU(I),GXT(I)
  160 READ (5,7100) SAT(I),SAC(I)
      IF (KTYPE.NE.3.AND.KTYPE.NE.4) GO TO 190
      IF (KDAM.NE.0) GO TO 190
      READ (5,7100) EC,GC,DC
  190 READ (5,7100) ((FG(I,J),I=1,MB),J=1,MG)
      READ(5,7100) DELTIM,TSTOP,PRINT
      IF(INOUT.EQ.0) GO TO 2100
C   PRINT OUT THE INPUT
      WRITE(6,7170)
      WRITE (6,7200) MG,MB,MBAR,NBAR,LBAR
      WRITE (6,7210) (MGM(I),I=1,MG)
      WRITE (6,7220) (NBN(I),I=1,MB)
      WRITE (6,7225) NSYMG,NSYMB,NPLT,NBND,NDERV
      WRITE (6,7150) NNOUT
      IF(NNOUT.GT.0) WRITE(6,7180) (MOUT(I),NOUT(I),I=1,NNOUT)
      WRITE (6,7185) NKP
      IF (NKP.GT.0) WRITE (6,7180) (KPG(I),KPB(I),I=1,NKP)
      WRITE (6,11600) NL,XLP
      IF(NPLT.EQ.0) WRITE(6,7230) THETAO
      IF(NPLT.EQ.1) WRITE(6,7260) THETAO,A
      IF (NDERV.EQ.2) GO TO 1180
      DO 1160 I=1,NL
 1160 WRITE (6,11700) I,HM(I),RHOM(I),EX(I),ET(I),XXNU(I),THNU(I),
     1  GXT(I),SAT(I),SAC(I)
      IF (KTYPE.NE.3.AND.KTYPE.NE.4) GO TO 1190
      IF (KDAM.NE.0) GO TO 1190
      WRITE (6,11900) EC,GC,DC
      GO TO 1190
 1180 WRITE (6,7280) (HM(I),RHOM(I),EM(I),I=1,NL)
      WRITE (6,7300) TNU,SIGO,EP,EPSIF
 1190 WRITE (6,7400) ((FG(I,J),I=1,MB),J=1,MG)
```

```
      WRITE(6,8200) DELTIM,TSTOP,PRINT
C
 2100 I=0
      MGMB=0
      DO 2150 M=1,MG
      MM = MGM(M)
      DO 2150 N=1,MB
      NN = NBN(N)
      MUSE(N,M)=1
      IF(I.EQ.NNOUT) GO TO 2130
      DO 2110 J=1,NNOUT
      IF(MM.EQ.MOUT(J).AND.NN.EQ.NOUT(J)) GO TO 2120
 2110 CONTINUE
      GO TO 2130
 2120 MUSE(N,M)=0
      I=I+1
      GO TO 2150
 2130 MGMB=MGMB+1
 2150 CONTINUE
      MGMB2=2*MGMB
      DO 2200 M=1,MG
      MM = MGM(M)
      CC1(M) = MM
 2200 CC5(M) = MM + 1
      XJ=180.0/THETAO
      IF(NPLT.EQ.0) XJ=PI/THETAO
      DO 2300 N=1,MB
      NN = NBN(N)
      CC2(N) = NN
 2300 CC6(N) = NN + 1
      RETURN
C
 7000 FORMAT(6I12)
 7100 FORMAT(6F12.1)
 7150 FORMAT (9H0NNOUT = I3)
 7170 FORMAT (24H1INPUT DATA FOR DEPROP  )
 7180 FORMAT (2I4)
 7185 FORMAT (7H0NKP = I3)
 7200 FORMAT(                        10H0MG      = I2/10H MB      = I
     12/10H MBAR    = I2/10H NBAR    = I2/10H LBAR    = I2)
```

DSET1

```
 7210 FORMAT (10HOMGM     = (10I5))
 7220 FORMAT (10HONBN     = (10I5))
 7225 FORMAT (10HONSYMG   = I2/10H NSYMB  = I2/10HONPLT   = I2/
    3 10H NBND    = I2/                10H NDERV  = I2)
 7230 FORMAT(17H THETAO, IN      = E16.8)
 7260 FORMAT(17H THETAO, DEG    = E16.8/17H A, IN            = E16.8)
 7280 FORMAT (12HO       HM, IN,4X,21HRHOM, LB-SEC**2/IN**4,4X,
    1  7HEM, PSI/(3E17.8))
 7300 FORMAT(17HOTNU               = E16.8/17H SIGD, PSI      = E16.8/17H EP,
    1 PSI         = E16.8/17H EPSIF, IN/IN  = E16.8)
 7400 FORMAT(6HOFG = /(5E14.6))
 8200 FORMAT(15HODELTIM, SEC = E16.8/15H TSTOP, SEC  = E16.8/15H PRINT
    1       = E16.8)
11600 FORMAT (10HONL       = I2/17HOXLP, IN          = E16.8)
11700 FORMAT (6HOLAYERI3/27H    HM, IN                         = E16.8/
    1  27H    RHOM, LB-SEC**2/IN**4 = E16.8/
    2  27H    EX, PSI               = E16.8/
    3  27H    ET, PSI               = E16.8/
    4  27H    XXNU                  = E16.8/
    5  27H    THNU                  = E16.8/
    6  27H    GXT, PSI              = E16.8/
    7  27H    SAT, PSI              = E16.8/
    8  27H    SAC, PSI              = E16.8)
11900 FORMAT (11HOEC, PSI = E16.8/11H GC, PSI = E16.8/
    1  11H DC, IN  = E16.8)
      END
```

```
*DECK DSET2
      SUBROUTINE DSET2
C
*CALL CBLK1
*CALL CBLK2
*CALL CBLK3
*CALL CBLK4
*CALL CBLK5
*CALL CBLK7
*CALL CBLK8
*CALL CBLK9
*CALL CBLK10
*CALL CBLK11
*CALL CBLK13
*CALL CNOVA
*CALL CBLANK
C
      IF (NDERV.EQ.1) GO TO 2710
      CALL LEGEND
      IF (LOAR.EQ.0) GO TO 3000
      IF (KTYPE.NE.3) GO TO 2500
C     SET UP EQUIVALENT LAYER FOR HONEYCOMB METAL, NDERV = 2.
      NELP = 2
      H2=HM(3)*0.5
      HD1=HM(3)-HM(2)
      HD2=HM(1)
      ZB(1)=-H2+0.5*HD2
      ZB(2) = H2 - .5*HD1
      SUMRH=0.0
      H0=0.0
      DO 2400 I=1,3
      H1=HM(I)
      SUMRH=SUMRH+RHOM(I)*(H1-H0)
 2400 H0=H1
      NL=1
      EQC=HM(3)-HM(2)+HM(1)
      EQH=(HM(3)+HM(2)-HM(1))*SQRT(3.0*HM(1)*(HM(3)-HM(2)))/EQC
      RHO=SUMRH/EQH
      H=EQH
      HM(1)=H
      EL=EM(1)*EQC/EQH
      EP=EP*EQC/EQH
      SIGO=SIGO*EQC/EQH
      EM(1)=EL
      IF(KDAM.EQ.2) GO TO 2705
      TCRIT(1)=EPSIF
      GO TO 2705
C     SINGLE LAYER, NDERV = 2.
 2500 H = HM(1)
      EL=EM(1)
      RHO=RHOM(1)
      H2=0.5*H
      ZB(1)=-H2
      ZB(2) = H2
      NELP = 2
      IF(KDAM-1) 2600,2700,2705
C   NO DAMAGE
 2600 TCRIT(1)=SIGO
      CCRIT(1)=SIGO
      NELP = 1
      GO TO 2705
 2700 TCRIT(1)=EPSIF
      IF(KTYPE.EQ.1) GO TO 2705
      TCRIT(1) = SIGO
      NELP = 1
 2705 DT = DELTIM
      F3=RHO*(1.0 - TNU**2)/EL
      F1 = H**2/(12.0*F3)
      F2= SIGO/RHO
      CALL DTSTEP (F1,F2,F3,F3,F1)
      IF (DT.GT.0.0) DELTIM = DT
      GO TO 2750
C
C     NDERV = 1.
C     COMPUTE HBAR.
 2710 A1 = 0.
      A2 = 0.
      A3 = 0.
      A4 = 0.
      A5 = 0.
```

DSET2

```
      A6 = 0.
      A7 = 0.
      A8 = 0.
      H0 = 0.
      DO 2715 I=1,NL
      H1 = HM(I)
      B22 = 1./(1. - XXNU(I)*THNU(I))
      B11 = EX(I)*B22
      B22 = ET(I)*B22
      B12 = XXNU(I)*B22
      B33 = GXT(I)
      BXL(I) = B11
      BTL(I) = B22
      D1 = H1 - H0
      D2 = H1**2 - H0**2
      A1 = A1 + B11*D2
      A2 = A2 + B11*D1
      A3 = A3 + B22*D2
      A4 = A4 + B22*D1
      A5 = A5 + B33*D2
      A6 = A6 + B33*D1
      A7 = A7 + B12*D2
      A8 = A8 + B12*D1
 2715 H0 = H1
      HB11 = .5*A1/A2
      HB22 = .5*A3/A4
      HB33 = .5*A5/A6
      HB12 = .5*A7/A8
      HBAR = .25*(HB11 + HB22 + HB33 + HB12)
C
      RHOBR = 0.
      CM11 = 0.
      CM12 = 0.
      CM22 = 0.
      CM33 = 0.
      FM11 = 0.
      FM12 = 0.
      FM22 = 0.
      FM33 = 0.
      DM11 = 0.
      DM12 = 0.
      DM22 = 0.
      DM33 = 0.
      F=0.0
      H0 = 0.
      DO 2720 I=1,NL
      H1 = HM(I)
      BTT = BTL(I)
      XNUB = XXNU(I)*BTT
      BXX = BXL(I)
      GXTL = GXT(I)
      RHOL = RHOM(I)
      H11 = H1 - H0
      F= F + SAT(I)*H11
      CM11 = CM11 + BXX*H11
      CM12 = CM12 + XNUB*H11
      CM22 = CM22 + BTT*H11
      CM33 = CM33 + GXTL*H11
      RHOBR = RHOBR + RHOL*H11
      H12 = H1**2 - H0**2
      H12D = H12 - 2.*HBAR*H11
      FM11 = FM11 + BXX*H12D
      FM12 = FM12 + XNUB*H12D
      FM22 = FM22 + BTT*H12D
      FM33 = FM33 + GXTL*H12D
      H13 = H1**3 - H0**3
      H13D = H13 - 3.*HBAR*H12 + 3.*HBAR**2*H11
      DM11 = DM11 + BXX*H13D
      DM12 = DM12 + XNUB*H13D
      DM22 = DM22 + BTT*H13D
      DM33 = DM33 + GXTL*H13D
 2720 H0 = H1
      OH3 = 1./HM(NL)
      OA = 1./A
      O2A2 = 1./(2.*A**2)
      O3A3 = 1./(3.*A**3)
      CM11 = CM11*OA
      CM12 = CM12*OA
      CM22 = CM22*OA
      CM33 = CM33*OA
      FM11 = FM11*O2A2
      FM12 = FM12*O2A2
      FM22 = FM22*O2A2
      FM33 = FM33*O2A2
      DM11 = DM11*O3A3
      DM12 = DM12*O3A3
      DM22 = DM22*O3A3
      DM33 = DM33*O3A3
      RHOBR = RHOBR*OH3
      RHO = RHOBR
      H = HM(NL)
      F3=RHO/OH3
      F1=DM22*A**3/F3
      F2=FV/F3
      F4 = F3/(A*CM11)
      F5 = DM11*A**3/F3
      F3=F3/(A*CM22)
      DT = DELTIM
      CALL DTSTEP (F1,F2,F3,F4,F5)
      IF (DT.GT.0.0) DELTIM = DT
      NELP = 1
      NZP = 2
      IF (KTYPE.EQ.5) GO TO 2730
      NLZ(1) = 1
      ZC(1) = -HBAR
      NLZ(2) = 1
      ZC(2) = ZC(1) + H
      IF (KTYPE.LT.3) GO TO 2745
      NLZ(2) = 3
      ZC(1) = ZC(1) + .5*HM(1)
      ZC(2) = ZC(2) - .5*(HM(3) - HM(2))
      GO TO 2745
 2730 HT = -HBAR
      HS = HM(1)
      DO 2740 I=1,NL
      NLZ(2*I - 1) = I
      NLZ(2*I) = I
      ZC(2*I - 1) = HT
      IF (I.GT.1) HS = HM(I) - HM(I-1)
      HT = HT + HS
```

```
2740 ZC(2*I) = HT
     NZP = 2*NL
2745 IF (KDAM.EQ.2) GO TO 2800
     DO 2747 I=1,NL
     TCRIT(I) = SAT(I)
2747 CCRIT(I) = SAC(I)
2750 CONTINUE
2800 RETURN
3000 KERR = 1
     RETURN
     END
```

DSET2

```
*DECK DSET3
      SUBROUTINE DSET3
C
*CALL CBLK1
*CALL CBLK2
*CALL CBLK3
*CALL CBLK4
*CALL CBLK5
*CALL CBLK7
*CALL CBLK8
*CALL CBLK9
*CALL CBLK10
*CALL CBLK11
*CALL CBLK13
*CALL CBLK14
*CALL CNOVA
*CALL CBLANK
C
C  PRINTOUT DESCRIPTION OF DEPROP DATA
C
 2800 WRITE(6,9300)
      IF(NPLT.EQ.0) WRITE(6,9400)
      IF(NPLT.EQ.1) WRITE(6,9500)
      GO TO (2820,2840,2860,2880,2900), KTYPE
 2820 WRITE (6,9600)
      GO TO 2950
 2840 WRITE (6,9700)
      GO TO 2950
 2860 WRITE (6,9800)
      GO TO 2950
 2880 WRITE (6,9820)
      GO TO 2950
 2900 WRITE (6,9840)
 2950 IF (NBND.EQ.1.OR.NBND.EQ.3.OR.NBND.EQ.6) WRITE (6,9900)
      IF (NBND.EQ.2.OR.NBND.EQ.4.OR.NBND.EQ.8) WRITE (6,9920)
      IF (NBND.EQ.5.OR.NBND.EQ.7.OR.NBND.EQ.9) WRITE (6,9940)
      IF (NBND.EQ.1.OR.NBND.EQ.4.OR.NBND.EQ.5) WRITE (6,9960)
      IF (NBND.EQ.2.OR.NBND.EQ.3.OR.NBND.EQ.7) WRITE (6,9980)
      IF (NBND.EQ.6.OR.NBND.EQ.8.OR.NBND.EQ.9) WRITE (6,10000)
      IF(MDERV.EQ.1) WRITE(6,10100)
      IF(NDERV.EQ.2) WRITE(6,10200)
      WRITE(6,10800) MG,MB,MBAR,NBAR,LBAR
      WRITE (6,10820)
      DO 2970 M=1,MG
      MM = MGM(M)
      DO 2970 N=1,MB
      NN = NBN(N)
      IF (MUSE(N,M).EQ.0) GO TO 2970
      WRITE (6,10830) MM,NN
 2970 CONTINUE
      WRITE (6,10850) XLP
      IF(NPLT.EQ.0) WRITE(6,10900) THETA0
      IF(NPLT.EQ.1) WRITE(6,11000)THETA0,A
      IF (NDERV.EQ.2) GO TO 3500
      WRITE (6,12050) HBAR,(I,I=1,NL)
      WRITE (6,12100) (HM(I),I=1,NL)
      WRITE (6,12200) (RHOM(I),I=1,NL)
      WRITE (6,12300) (EX(I),I=1,NL)
      WRITE (6,12400) (ET(I),I=1,NL)
      WRITE (6,12500) (XXNU(I),I=1,NL)
      WRITE (6,12600) (THNU(I),I=1,NL)
      WRITE (6,12650) (GXT(I),I=1,NL)
      IF (KTYPE.NE.1.AND.KTYPE.NE.3) GO TO 3300
      WRITE (6,12900) (SAT(I),I=1,NL)
      WRITE (6,13000) (SAC(I),I=1,NL)
      GO TO 3400
 3300 WRITE (6,12700) (SAT(I),I=1,NL)
      WRITE (6,12800) (SAC(I),I=1,NL)
 3400 IF (KTYPE.NE.3.AND.KTYPE.NE.4) GO TO 3600
      IF (KDAM.NE.0) GO TO 3600
      WRITE (6,13100) EC,GC,DC
      GO TO 3600
 3500 WRITE (6,11100) H,RHO,EL,TNU,SIGO,EP,EPSIF
 3600 WRITE (6,11200) ((FG(N,M),N=1,MB),M=1,MG)
      WRITE(6,11300) DELTIM,TSTOP,PRINT
      IF (NDERV.EQ.1) GO TO 4020
      DO 4000 K=1,LBAR
      ZH(K)=GX(K)*H*0.5
      ZF(K)=ZH(K)/A
      ZG(K)=GX(K)**2
```

```
4000 CONTINUE
     ZA(1) = ZB(1)/A
     ZA(2) = ZB(2)/A
     INZ(1) = 1
     INZ(2) = LBAR
4020 NNSYMG = 0
     NNSYMB = 0
     IF (NBND.EQ.5.OR.NBND.EQ.7.OR.NBND.EQ.9) NNSYMG = 1
     IF (NBND.EQ.6.OR.NBND.GE.8) NNSYMB = 1
     IF (NNSYMG.EQ.1.AND.NSYMG.EQ.0) WRITE (6,13200)
     IF (NNSYMB.EQ.1.AND.NSYMB.EQ.0) WRITE (6,13200)
     NGT = MBAR
     NBT = NBAR
     NG = NGT
     NB = NBT
     IF (NSYMG.EQ.1) NG = (NGT+1)/2
     IF (NSYMB.EQ.1) NB = (NBT+1)/2
     NY2 = 3*MGMB
     PIM = PI/FLOAT(2*(MBAR-1))
     PIN = PI/FLOAT(2*(NBAR-1))
     IF (NSYMG.EQ.1) PIM = 2.*PIM
     IF (NSYMB.EQ.1) PIN = 2.*PIN
     R=A/H
     XL=XLP/(PI*A)
     XL1=1.0/XL
     XL2=XL**2
     XL3=2.0*XL1
     XL4=2.0*XL2
     XL5=XL4*R
     XL7=1.0/XL2
     CN8 = XL**2
     CN9 = CN8/(2.0*R)
     IF (NDERV.EQ.1) GO TO 4040
     C1 = 1.0/(A**2*XL**3)
     C2 = (XJ/A)**2/XL
     C3 = (XJ/A)**2*XJ
     C4 = XJ/(A*XL)**2
     C5 = -H**2/2.0
     C6 = H**3/8.0
     DELK = PIM*XLP/PI
```

```
      DELT = PIN*THETAO/PI
      DELT = A*DELT
      CN10 = 2.0*CN8
      CN11 = CN9/(3.0*R)
      GO TO 4050
 4040 CN10 = 2.*CN8*R
      CN11 = CN10
      C1 = DM11*A/XL**3
      C2 = (DM12 + 4.0*DM33)*A*XJ**2/XL
      C3 = DM22*A*XJ**3
      C4 = (DM12 + 4.0*DM33)*A*XJ/XL**2
      C5 = -4.0*DM33*XJ*A**2/XL
 4050 XJ2 = XJ**2
      XJ3=XJ*XL1
      XJ4=2.0*XJ
      XJ5=2.0*XJ3
      DPRT1=PRINT*DELTIM
      XLP1=XL5
      XLP2=2.0*XL*R
      PRL = 1./(RHO*XLP**2)
C     SIMPSON S RULE.
C     MBAR AND NBAR MUST BE ODD NUMBERS FOR FULL PANEL.
      DO 4100 I=1,MBAR
      F = I-1
      GAM(I) = F*PIM
      XG(I) = GAM(I)*XLP/PI
      PIMA(I) = PRL*4.*PIM/3.
      IF (NSYMG.EQ.1) PIMA(I) = .5*PIMA(I)
      IF ((I+1)/2.EQ.I/2) PIMA(I) = 2.*PIMA(I)
 4100 CONTINUE
      PIMA(1) = PIMA(1)*.5
      PIMA(MBAR) = PIMA(MBAR)*.5
      DO 4200 I=1,NBAR
      F = I-1
      BETR(I) = F*PIN
      XB(I) = BETR(I)*THETAO/PI
      PINA(I) =     4.*PIN/3.
      IF (NSYMB.EQ.1) PINA(I) = .5*PINA(I)
      IF ((I+1)/2.EQ.I/2) PINA(I) = PINA(I)*2.
 4200 CONTINUE
```

DSET3

```
      PINA(1) = .50*PINA(1)
      PINA(NBAR) = PINA(NBAR)*.5
      DO 4400 I=1,MBAR
      DO 4400 J=1,NBAR
      NBUSE(J,I) = 0
4400  NUSE(J,I) = 2
      II = 0
      DO 4430 I=1,NGT
      DO 4430 J=1,NBT
      IF (II.EQ.NKP) GO TO 4430
      DO 4410 K=1,NKP
      IF (I.EQ.KPG(K).AND.J.EQ.KPB(K)) GO TO 4420
4410  CONTINUE
      GO TO 4430
4420  NUSE(J,I) = 3
      II = II + 1
4430  CONTINUE
      N1 = NBAR - NSYMB
      K = 0
      DO 4440 J=2,N1
      K = K + 1
      IF (NUSE(J,1).GT.2) NBUSE(J,1) = -K
      IF (NSYMG.EQ.1.AND.NUSE(J,MBAR).GT.2) NBUSE(J,MBAR) = -K-N1+1
4440  CONTINUE
      N1 = MBAR - NSYMG
      K = 0
      DO 4450 I=2,N1
      K = K + 1
      IF (NUSE(1,I).GT.2) NBUSE(1,I) = K
      IF (NSYMB.EQ.1.AND.NUSE(NBAR,I).GT.2) NBUSE(NBAR,I) = K+N1-1
4450  CONTINUE
      NBUSE(1,1) = 101
      IF (NSYMB.EQ.1) NBUSE(NBAR,1) = 102
      IF (NSYMG.EQ.1) NBUSE(1,MBAR) = 103
      IF (NSYMG*NSYMB.EQ.1) NBUSE(NBAR,MBAR) = 104
      NRC = 1 + NSYMB + 2*NSYMG
      II=0
      DO 4500 M=1,MG
      X1 = MGM(M) + 1
      DO 4500 I=1,NGT
      II=II+1
      SING(II)=SIN(X1*GAM(I))
      COSG(II)=COS(X1*GAM(I))
      SIN2G(II)=SIN((X1-1.0)*GAM(I))
      COS2G(II)=COS((X1-1.0)*GAM(I))
 4500 CONTINUE
      II=0
      DO 4600 N=1,MB
      X1 = NBN(N) + 1
      DO 4600 J=1,NBT
      II=II+1
      SINB(II)=SIN(X1*BETR(J))
      COSB(II)=COS(X1*BETR(J))
      SIN2B(II)=SIN((X1-1.0)*BETR(J))
      COS2B(II)=COS((X1-1.0)*BETR(J))
 4600 CONTINUE
C
      CALL BOLT
C
 4800 K=0
      OA=1.0/A
      DO 5200 I=1,NGT
      DO 5200 J=1,NBT
      IF(NUSE(J,I).EQ.0) GO TO 5200
      K=K+1
      DWD(K)=0.0
      DWG(K)=0.0
      DWB(K)=0.0
      DO 5100 M=1,MG
      MM=(M-1)*NGT + I
      DO 5100 N=1,MB
      IF(MUSE(N,M).EQ.0) GO TO 5100
      NN=(N-1)*NBT + J
      FGMN=FG(N,M)*OA
      DWD(K) = FGMN*FP1(MM)*FP5(NN) + DWD(K)
      DWG(K) = FGMN*FP2(MM)*FP5(NN) + DWG(K)
      DWB(K) = FGMN*FP1(MM)*FP6(NN) + DWB(K)
 5100 CONTINUE
 5200 CONTINUE
      NGNBT = K
```

DSET3

```
      LMAX = LBAR*NGNBT
      NGNB = NG*NB
      RETURN
 9300 FORMAT(1H1,25X,13HD E P R O P  /15HOPANEL ANALYZED)
 9400 FORMAT(7H   FLAT)
 9500 FORMAT(9H   CURVED)
 9600 FORMAT(22H   METAL, SINGLE LAYER)
 9700 FORMAT(24H   PLASTIC, SINGLE LAYER)
 9800 FORMAT(19H   METAL, HONEYCOMB)
 9820 FORMAT (21H   PLASTIC, HONEYCOMB)
 9840 FORMAT (22H   PLASTIC, MULTILAYER)
 9900 FORMAT (37H   CLAMPED - CLAMPED, GAMMA DIRECTION)
 9920 FORMAT (35H   SIMPLE - SIMPLE, GAMMA DIRECTION)
 9940 FORMAT (36H   CLAMPED - SIMPLE, GAMMA DIRECTION)
 9960 FORMAT (36H   CLAMPED - CLAMPED, BETA DIRECTION)
 9980 FORMAT (34H   SIMPLE - SIMPLE, BETA DIRECTION)
10000 FORMAT (35H   CLAMPED - SIMPLE, BETA DIRECTION)
10100 FORMAT(26HORESPONSE OPTION - ELASTIC)
10200 FORMAT(34HORESPONSE OPTION - ELASTIC-PLASTIC)
10800 FORMAT(17HOSTRUCTURAL MODEL/
     1 47H   NUMBER OF GAMMA MODES (MG)                    = I3/
     2 47H   NUMBER OF BETA MODES  (MB)                    = I3/
     3 47H0  NUMBER OF GAMMA INTEGRATION POINTS (MBAR) = I3/
     4 47H   NUMBER OF BETA INTEGRATION POINTS  (NBAR) = I3/
     5 47H   NUMBER OF Z INTEGRATION POINTS     (LBAR) = I3)
10820 FORMAT (24HOMODAL COMBINATIONS USED)
10830 FORMAT (3X,2I4)
10850 FORMAT (35H0  LENGTH OF PANEL, IN (XLP)     = E16.8)
10900 FORMAT(35H   WIDTH OF PANEL, IN (THETA0)   = E16.8)
11000 FORMAT(35H   SUBTENDED ANGLE, DEG (THETA0) = E16.8/
     2 35H   RADIUS, IN (A)                  = E16.8)
11100 FORMAT(35H   THICKNESS, IN                 = E16.8/
     1  35H   DENSITY, LB-SEC**2/IN**4      = E16.8/
     2 35H   ELASTIC MODULUS, PSI          = E16.8/
     3 35H   POISSON'S RATIO               = E16.8/
     4 35H   YIELD STRESS, PSI             = E16.8/
     5 35H   STRAIN HARDENING SLOPE, PSI   = E16.8/
     6 35H   ULTIMATE STRAIN, IN/IN (EPSIF)= E16.8)
11200 FORMAT(26HOINITIAL IMPERFECTIONS, IN/(5E14.6))
11300 FORMAT(17HOTIME INFORMATION/
     1 42H    INTEGRATION STEP SIZE, SEC (DELTIM)  = E16.8/
     2 42H    STOP TIME, SEC (TSTOP)               = E16.8/
     3 42H    PRINT FREQUENCY (PRINT)              = E16.8)
12050 FORMAT (40HOCOORDINATE SURFACE POSITION (HBAR), IN   E16.8/
     1  13HOLAYER NUMBER,22X,4I15/(31X,4I15))
12100 FORMAT (27H    CUMULATIVE THICKNESS, IN,13X,6E15.6)
12200 FORMAT (32H    MASS DENSITY, LB-SEC**2/IN**4,8X,6E15.6)
12300 FORMAT (33H    MODULUS OF ELASTICITY - X, PSI,7X,6E15.6)
12400 FORMAT (40H    MODULUS OF ELASTICITY - THETA, PSI    6E15.6)
12500 FORMAT (22H    POISSON'S RATIO - X,18X,6E15.6)
12600 FORMAT (26H    POISSON'S RATIO - THETA,14X,6E15.6)
12700 FORMAT (31H    TENSILE ULTIMATE STRESS, PSI,9X,6E15.6)
12800 FORMAT (35H    COMPRESSIVE ULTIMATE STRESS, PSI,5X,6E15.6)
12900 FORMAT (28H    TENSILE YIELD STRESS, PSI,12X,6E15.6)
13000 FORMAT (32H    COMPRESSIVE YIELD STRESS, PSI,8X,6E15.6)
12650 FORMAT (21H    SHEAR MODULUS, PSI,19X,6E15.6)
13100 FORMAT (62HOCORE MODULUS OF ELASTICITY PARALLEL TO CORE DEPTH (EC)
     1, PSI = E15.6/
     2  63H SHEAR MODULUS OF CORE (GC), PSI                           =
     3  E14.6/
     4  62H CORE CELL SIZE (DC), IN                                   =
     5  E15.6)
13200 FORMAT (41HO** WARNING **  INCONSISTENCY IN SYMMETRY)
      END
```

```
*DECK DTSTEP
      SUBROUTINE DTSTEP (F1,F2,F3,F4,F5)
C
C     THIS SUBROUTINE COMPUTES AN APPROXIMATE, CONSERVATIVE
C     TIME STEP FOR DEPROP.
C     NOTE:  IT IS ASSUMED THAT FOR A FLAT PANEL THETAO .LT. XL.
C
*CALL CBLK1
*CALL CBLK2
*CALL CBLK13
*CALL CNOVA
C
      BN = NBAR
      IF (NSYMB.EQ.0) BN = 2*NBAR - 1
      THETR = PI*THETAO/180.
      BM = MBAR
      IF (NSYMB.EQ.0) BM = 2*MBAR - 1
      CM=0.0
      IF(NBND.EQ.1 .OR. NBND.EQ.3 .OR. NBND.EQ.6) CM=0.30
      IF(NBND.EQ.5 .OR. NBND.EQ.7 .OR. NBND.EQ.9) CM=0.15
      CN=0.0
      IF(NBND.EQ.1 .OR. NBND.EQ.4 .OR. NBND.EQ.5) CN=0.30
      IF(NBND.EQ.6 .OR. NBND.GE.8) CN=0.15
      DT1X = 1.0E6
      DT2X = 1.0E6
      DT3X = 1.0E6
      DT4X = 1.0E6
      DT5X = 1.0E6
      IF (NPLT.EQ.0) DT2X = THETAO*SQRT(F3)/(BN - 1.0)
      IF (NPLT.EQ.1) DT3X = A*THETR*SQRT(F3)/(BN - 1.0)
      IF (NPLT.EQ.1) DT4X = XLP*SQRT(F4)/(BM - 1.0)
C     CHECK ALL MODAL COMBINATIONS.
      DO 200 M=1,MG
      BARM = MGM(M)
      DO 200 N=1,MB
      IF (MUSE(N,M).EQ.0) GO TO 200
      BARN = NBN(N)
      BARMX=BARM + CM
      BARNX = BARN + CN
      IF(NPLT.EQ.1) GO TO 100
```

```
C     FLAT PANEL
      ELMN = (BARMX*PI/XLP)**2 + (BARNX*PI/THETA0)**2
      DT1 = PI       /SQRT(ELMN*(F2 + ELMN*F1))
      DT1 = DT1 / 25.0
      IF (DT1.LT.DT1X) DT1X = DT1
      GO TO 200
C
C     CURVED PANEL
  100 ELMN = BARMX*PI*A/XLP
      EKMN = BARNX*PI/THETR
      DUM = (ELMN**2 + EKMN**2)**2
      DT1 = PI*A        *SQRT(F3/(0.5*(1.0 + ELMN**2) - 0.5*SQRT((1.0 -
     1 ELMN**2)**2 + 4.0*(0.30*ELMN)**2)))
      DT1 = DT1/35.0
      DT2 = PI*A        /SQRT(F1*DUM/A**2 + ELMN**4/(F3*DUM))
      DT2 = DT2/35.0
      ELMN = SQRT(DUM)/A**2
      DT5 = PI        /SQRT(ELMN*(F2 + ELMN*F5))
      DT5 = DT5/25.0
      IF (DT1.LT.DT1X) DT1X = DT1
      IF (DT2.LT.DT2X) DT2X = DT2
      IF (DT5.LT.DT5X) DT5X = DT5
  200 CONTINUE
      IF (NPLT.EQ.0) DELTIM = AMIN1(DT1X,DT2X)
      IF (NPLT.EQ.1) DELTIM = AMIN1(DT1X,DT2X,DT3X,DT4X,DT5X)
      IF (NDBUG.GT.0) WRITE (6,1000) DT1X,DT2X,DT3X,DT4X,DT5X
      RETURN
C
 1000 FORMAT (30H0DEPROP TIME STEP CALCULATIONS/5E15.6)
      END
```

```
*DECK HIM
      SUBROUTINE HIM (K,NEQ,DELTIM,TIME,VXO,X4,AX4)
C
C     SPECIAL INTEGRATION METHOD FOR 2ND ORDER DIFFERENTIAL EQUATIONS
C       WHICH HAVE NO DAMPING.  CENTRAL DIFFERENCE SCHEME.
C
      COMMON/CHIM/ X3(147),DTSQ
      DIMENSION X4(1),AX4(1),VXO(1)
C
      IF (K.GT.1) GO TO 200
      DTSQ = DELTIM**2
      K = 2
      DO 100 I=1,NEQ
  100 X3(I) = X4(I) - VXO(I)*DELTIM + 0.5*DTSQ*AX4(I)
C
  200 DO 300 I=1,NEQ
      X = 2.*X4(I) - X3(I) + DTSQ*AX4(I)
      X3(I) = X4(I)
  300 X4(I) = X
      TIME = TIME + DELTIM
      RETURN
      END
```

```
*DECK LEGEND
      SUBROUTINE LEGEND
C
C     THIS ROUTINE CONTAINS THE LEGENDRE ZEROES AND
C     WEIGHTING FACTORS FOR LBAR .LE. 14.
C
*CALL CBLK1
*CALL CBLK3
      DIMENSION CCX(7,14), CHO(7,14)
C
      DATA CCX/7*0.0,0.57735026918963,6*0.0,0.77459666924148,
     1 6*0.0,0.86113631159405,0.33998104358486,5*0.0,0.90617984593866,
     2 0.53846931010568,5*0.0,0.93246951420315,0.66120938646626,
     3 0.23861918608320,4*0.0,0.94910791234276,0.74153118559939,
     4 0.40584515137740,4*0.0,0.96028985649754,0.79666647741363,
     5 0.52553240991633,0.18343464249565,3*0.0,0.96816023950763,
     6 0.83603110732664,0.61337143270059,0.32425342340381,3*0.0,
     7 0.97390652851717,0.86506336668898,0.67940956829902,
     8 0.43339539412925,0.14887433898163,2*0.0,0.97822865814606,
     9 0.88706259976809,0.73015200557405,0.51909612920681,
     1 0.26954315595234,2*0.0,0.98156063424672,0.90411725637047,
     2 0.76990267419430,0.58731795428662,0.36783149899818,
     3 0.12523340851147,0.0,0.98418305471859,0.91759839922298,
     4 0.80157809073331,0.64234933944034,0.44849275103645,
     5 0.23045831595514,0.0,0.98628380869681,0.92843488366357,
     6 0.82720131506976,0.68729290481168,0.51524863635815,
     7 0.31911236892789,0.10805494870734/
C
      DATA CHO/7*0.0,1.0,6*0.0,0.55555555555556,0.88888888888889,
     1 5*0.0,0.34785484513745,0.65214515486255,5*0.0,0.23692688505619,
     2 0.47862867049937,0.56888888888889,4*0.0,0.17132449237917,
     3 0.36076157304814,0.46791393457269,4*0.0,0.12948496616887,
     4 0.27970539148928,0.38183005050512,0.41795918367347,3*0.0,
     5 0.10122853629038,0.22238103445337,0.31370664587789,
     6 0.36268378337836,3*0.0,0.81274388361574E-1,0.18064816069486,
     7 0.26061069640293,0.31234707704000,0.33023935500126,2*0.0,
     8 0.66671344308688E-1,0.14945134915058,0.21908636251598,
     9 0.26926671931000,0.29552422471475,2*0.0,0.55668567116174E-1,
     1 0.12558036946491,0.18629021092773,0.23319376459199,
     2 0.26280454451025,0.27292508677790,0.0,0.47175336386512E-1,
     3 0.10693932599532,0.16007832854335,0.20316742672307,
     4 0.23349253653835,0.24914704581340,0.0,0.40484004765316E-1,
     5 0.92121499837728E-1,0.13887351021979,0.17814598076195,
     6 0.20781604753689,0.22628318026290,0.23255155323087,
     7 0.35119460331752E-1,0.80158087159760E-1,0.12151857068790,
     8 0.15720316715819,0.18553839747794,0.20519846372130,
     9 0.21526385346316/
C
      IF (LBAR.LE.0) GO TO 400
      IF(LBAR.GT.14) GO TO 400
      N = (LBAR+1)/2
      NEV = 0
      IF(N.EQ.LBAR/2) NEV = 1
      DO 300 J=1,N
      HGO(J) = CHO(J,LBAR)
      GX(J) = -CCX(J,LBAR)
      IF(J.EQ.N.AND.NEV.EQ.0) GO TO 300
      M = LBAR - J + 1
      GX(M) = -GX(J)
      HGO(M) = HGO(J)
  300 CONTINUE
  350 RETURN
C
  400 WRITE(6,1000) LBAR
 1000 FORMAT (29HOTHE VALUE OF LBAR IS INVALID/
     1    8HOLBAR = I4)
      LBAR = 0
      RETURN
      END
```

LEGEND

```
*DECK LIST1
      SUBROUTINE LIST1
C
C       THIS SUBROUTINE PRINTS AND/OR CHECKS CRITICAL STRAINS, STRESS AND
C       DISPLACEMENTS FOR THE MULTILAYER (NOERV=1) METHOD.
C
C     KZ- PRINT CODE
C        0, RETURN
C        1, COMPUTATIONS ONLY
C        2, DON'T CHECK MAX BUT DO PRINT
C        3, CHECK MAX AND PRINT
C     NUSE - USE CODE FOR SPATIAL POINTS.
C        0, NO USE.
C        1, PRINT ONLY.
C        2, INTEGRATION PURPOSES ONLY.
C        3, PRINTOUT, TOO.
*CALL CBLK1
*CALL CBLK8
*CALL CBLK9
*CALL CBLK10
*CALL CBLK14
*CALL CNOVA
*CALL CBLANK
C
      DATA FL1/2H  /,FL2/2H */
C
      IF(KZ.EQ.0) GO TO 1000
      IF(KZ.EQ.1) GO TO 10
      IF (NCALL.EQ.0) WRITE (6,5000) TIME
      WRITE (6,5100)
      DO 5 I=1,MG
      M = MGM(I)
      DO 5 J=1,MB
      N = NBN(J)
      IF(MUSE(J,I).EQ.0) GO TO 5
      WRITE(6,5200) M,N,UU(J,I),VV(J,I),WW(J,I)
    5 CONTINUE
      IF (NKP.EQ.0) GO TO 1000
      IF(NPLT.EQ.0) WRITE(6,5800)
      IF(NPLT.EQ.1) WRITE(6,5300)
```

```
   10 M=0
      DO 750 I=1,NGT
      X = XG(I)
      DO 700 J=1,NBT
      NNUSE = NUSE(J,I)
      IF (NNUSE.EQ.0) GO TO 700
      M = M + 1
      IF (NNUSE.LT.2) GO TO 700
      IF (KZ.EQ.2.AND.NNUSE.EQ.2) GO TO 700
      TH=XB(J)
      EXX = X1A(M)
      ETT = X2A(M)
      EXT = X3A(M)
      XKXX = X4A(M)
      XKTT = X5A(M)
      XKXT = X6A(M)
      DO 650 K=1,NZP
      II = NLZ(K)
      S2 = ZC(K)/A
      X1 = EXX + S2*XKXX
      X2 = ETT + S2*XKTT
      X3 = EXT + S2*XKXT
      SIGXX = BXL(II)*(X1 + THNU(II)*X2)
      SIGTT = BTL(II)*(X2 + XXNU(II)*X1)
      SIGXT = GXT(II)*X3
C     PRINCIPAL STRESSES.
      SIG = SQRT(.25*(SIGXX - SIGTT)**2 + SIGXT**2)
      S1 = (SIGXX + SIGTT)*.5
      SIG1 = S1 + SIG
      SIG2 = S1 - SIG
  600 FLAG = FL1
      IF (SIG1.GT.SAT(II)) FLAG = FL2
      IF (SIG2.LT.-SAC(II)) FLAG = FL2
      WRITE (6,5400) X,TH,ZC(K),X1,X2,X3,SIGXX,SIGTT,SIGXT,FLAG
  650 CONTINUE
  700 CONTINUE
  750 CONTINUE
      IF (KZ.LT.2) GO TO 1000
C
      WRITE (6,6000)
      DO 770 I=1,MBAR
      X = XG(I)
      DO 770 J=1,NBAR
      NBC = NBUSE(J,I)
      IF (NBC.EQ.0.OR.NBC.GT.100) GO TO 770
      Y = XB(J)
      IF (NBC.GT.0) GO TO 760
      NC = -NBC
      WRITE (6,6100) X,Y,VRX(NC),ENX(NC)
      GO TO 770
  760 WRITE (6,6100) X,Y,VRT(NBC),ENT(NBC)
  770 CONTINUE
      IF (NBND.EQ.1) GO TO 790
      WRITE (6,6200)
      DO 780 I=1,NRC
      X = XG(1)
      IF (I.GT.2) X = XG(MBAR)
      Y = XB(1)
      IF (I.EQ.2.OR.I.EQ.4) Y = XB(NBAR)
      WRITE (6,6100) X,Y,RR(I)
  780 CONTINUE
C
  790 IF (NPLT.EQ.0) WRITE (6,5700)
      IF (NPLT.EQ.1) WRITE (6,5500)
      KKK = 0
      DO 900 I=1,NGT
      X = XB(I)
      DO 800 J=1,NBT
      NNUSE = NUSE(J,I)
      IF (NNUSE.EQ.0) GO TO 800
      KKK = KKK + 1
      IF (NNUSE.LE.2) GO TO 800
      IF (NU.EQ.0) PPP = P(KKK)
      UF = A*U(KKK)
      VF = A*V(KKK)
      WF = A*W(KKK)
      WRITE (6,5600) X,XB(J),UF,VF,WF,PPP
C
  800 CONTINUE
  900 CONTINUE
```

```
 1000 RETURN
C
 5000 FORMAT (//1H0,3HT =,E15.7,4H SEC)
 5100 FORMAT (1H0,2X,5HGAMMA,3X,4HBETA,8X,3HURS,13X,3HVRS,13X,3HWRS)
 5200 FORMAT (I5,I7,2X,3E16.7)
 5300 FORMAT (1H0,3X,1HX,3X,5H BETA,5X,1HZ,10X,3HEXX,12X,3HETT,12X,
     1  3HEXT,9X,8HSIGMA XX,7X,8HSIGMA TT,7X,8HSIGMA XT/
     2  2X,4H(IN),2X,5H(DEG),3X,4H(IN),6X,7H(IN/IN),8X,7H(IN/IN),
     3  8X,7H(IN/IN),9X,5H(PSI),10X,5H(PSI),10X,5H(PSI))
 5400 FORMAT (1X,F5.2,2X,F8.2,1X,F7.4,6E15.6,2X,A2)
 5500 FORMAT (1H0,7X,5HX(IN),9X,10H BETA(DEG),8X,5HU(IN),
     1  11X,5HV(IN),11X,5HW(IN),6X,14HPRESSURE (PSI))
 5600 FORMAT (1X,6E16.7)
 5700 FORMAT (1H0,7X,5HX(IN),12X,5HY(IN),10X,5HU(IN),
     1  11X,5HV(IN),11X,5HW(IN),6X,14HPRESSURE (PSI))
 5800 FORMAT (1H0,3X,1HX,6X,1HY,6X,1HZ,10X,3HEXX,12X,3HETT,12X,
     1  3HEXT,9X,8HSIGMA XX,7X,8HSIGMA TT,7X,8HSIGMA XT/
     2  2X,4H(IN),3X,4H(IN),3X,4H(IN),6X,7H(IN/IN),8X,7H(IN/IN),
     3  8X,7H(IN/IN),9X,5H(PSI),10X,5H(PSI),10X,5H(PSI))
 5900 FORMAT(27H0DEFLECTION AT CENTER,IN = E15.8)
 6000 FORMAT (51H0REACTIVE FORCES PER UNIT LENGTH ALONG EDGE (LB/IN)/
     1  6X,1HX,8X,1HY,9X,1HV,14X,1HN)
 6100 FORMAT (2F8.3,2E15.6)
 6200 FORMAT (33H0REACTIVE FORCES AT CORNERS (LBS))
      END
```

```
*DECK LIST2
      SUBROUTINE LIST2
C     THIS SUBROUTINE PRINTS AND/OR CHECKS STRAINS, STRESSES, AND
C       DISPLACEMENTS FOR THE SINGLE LAYER (NDERV=2) METHOD.
C
C     KZ- PRINT CODE
C        0, RETURN
C       1, COMPUTATIONS ONLY
C        2, DON'T CHECK MAX BUT DO PRINT
C        3, CHECK MAX AND PRINT
C     NUSE - USE CODE FOR SPATIAL POINTS.
C       0, NO USE.
C       1, PRINT ONLY.
C       2, INTEGRATION PURPOSES ONLY.
C       3, PRINTOUT, TOO.
C
*CALL CBLK1
*CALL CBLK7
*CALL CBLK8
*CALL CBLK9
*CALL CBLK10
*CALL CBLK14
*CALL CNOVA
*CALL CBLANK
C
      DATA FL1/2H  /,FL2/2H */
      IF(KZ.EQ.0) GO TO 1000
      IF(KZ.EQ.1) GO TO 10
      IF (NCALL.EQ.0) WRITE (6,5000) TIME
      WRITE (6,5100)
      DO 5 I=1,MG
      M = MGM(I)
      DO 5 J=1,MB
      IF(MUSE(J,I).EQ.0) GO TO 5
      N = NBN(J)
      WRITE(6,5200) M,N,UU(J,I),VV(J,I),WW(J,I)
  5   CONTINUE
      IF (NKP.EQ.0) GO TO 1000
      IF(NPLT.EQ.0) WRITE(6,5800)
      IF(NPLT.EQ.1) WRITE(6,5300)
```

LIST2

```
10   M=0
     DO 300 I=1,NGT
     X = XG(I)
     DO 200 J=1,NBT
     NNUSE = NUSE(J,I)
     IF (NNUSE.EQ.0) GO TO 200
     M = M + 1
     IF (NNUSE.LT.2) GO TO 200
     IF (KZ.EQ.2.AND.NNUSE.EQ.2) GO TO 200
     JI = LBAR*(M-1)
     TH=XB(J)
     EXX = X1A(M)
     ETT = X2A(M)
     EXT = X3A(M)
     XKXX = X4A(M)
     XKTT = X5A(M)
     XKXT = X6A(M)
     DO 100 KK=1,2
     K = INZ(KK)
     L = JI + K
     S2 = ZA(KK)
     S1 = S2
     IF (NELP.EQ.2) S1 = ZF(K)
     FLAG=FL1
     IF (NELP.EQ.1.AND.EPSO(L).GT.SIGO2) FLAG = FL2
     X1=EXX + S2*XKXX
     X2= ETT +S2*XKTT
     X3= EXT + S2*XKXT
     IF (NELP.EQ.2) GO TO 15
     SIG1 = S1A(M) + S2*S4A(M)
     SIG2 = S2A(M) + S2*S5A(M)
     SIG3 = S3A(M) + S2*S6A(M)
     GO TO 60
  15 SIG1 = SXX(L)
     SIG2 = STT(L)
     SIG3 = SXT(L)
  60 IF (NNUSE.EQ.2) GO TO 100
     IF (KZ.EQ.1) GO TO 100
     WRITE (6,5400) X,TH,ZB(KK),X1,X2,X3,SIG1,SIG2,SIG3,KY(L),FLAG
 100 CONTINUE
 200  CONTINUE
 300  CONTINUE
      IF(KZ.LT.2) GO TO 1000
C
      WRITE (6,6000)
      DO 370 I=1,MBAR
      X = XG(I)
      DO 370 J=1,NBAR
      NBC = NBUSE(J,I)
      IF (NBC.EQ.0.OR.NBC.GT.100) GO TO 370
      Y = XB(J)
      IF (NBC.GT.0) GO TO 360
      NC = -NBC
      WRITE (6,6100) X,Y,VRX(NC),ENX(NC)
      GO TO 370
 360  WRITE (6,6100) X,Y,VRT(NBC),ENT(NBC)
 370  CONTINUE
      IF (NBND.EQ.1) GO TO 390
      WRITE (6,6200)
      DO 380 I=1,NRC
      X = XG(1)
      IF (I.GT.2) X = XG(MBAR)
      Y = XB(1)
      IF (I.EQ.2.OR.I.EQ.4) Y = XB(NBAR)
      WRITE (6,6100) X,Y,RR(I)
 380  CONTINUE
C
 390  IF(NPLT.EQ.0) WRITE(6,5700)
      IF(NPLT.EQ.1) WRITE(6,5500)
      KKK=0
      DO 500 I=1,NGT
      X = XG(I)
      DO 400 J=1,NBT
      NNUSE = NUSE(J,I)
      IF (NNUSE.EQ.0) GO TO 400
      KKK = KKK + 1
      IF (NNUSE.LE.2) GO TO 400
      IF (NU.EQ.0) PPP = P(KKK)
      UF = A*U(KKK)
      VF = A*V(KKK)
```

LIST2

```
      WF = A*W(KKK)
      WRITE (6,5600) X,XB(J),UF,VF,WF,PPP
  400 CONTINUE
  500 CONTINUE
C
 1000 RETURN
C
 5000 FORMAT (//1H0,3HT =,E15.7,4H SEC)
 5100 FORMAT (1H0,2X,5HGAMMA,3X,4HBETA,8X,3HURS,13X,3HVRS,13X,3HWRS)
 5200 FORMAT (I5,I7,2X,3E16.7)
 5300 FORMAT (1H0,3X,1HX,3X,5H BETA,5X,1HZ,10X,3HEXX,12X,3HETT,12X,
     1  3HEXT,9X,8HSIGMA XX,7X,8HSIGMA TT,7X,8HSIGMA XT,3X,6HREGION/
     2  2X,4H(IN),2X,5H(DEG),3X,4H(IN),6X,7H(IN/IN),8X,7H(IN/IN),
     3  8X,7H(IN/IN),9X,5H(PSI),10X,5H(PSI),10X,5H(PSI))
 5400 FORMAT (1X,F5.2,2X,F5.2,1X,F7.4,6E15.6,I4,A2)
 5500 FORMAT (1H0,7X,5HX(IN),9X,10H BETA(DEG),8X,5HU(IN),
     1  11X,5HV(IN),11X,5HW(IN),6X,14HPRESSURE (PSI))
 5600 FORMAT (1X,6E16.7)
 5700 FORMAT (1H0,7X,5HX(IN),12X,5HY(IN),10X,5HU(IN),
     1  11X,5HV(IN),11X,5HW(IN),6X,14HPRESSURE (PSI))
 5800 FORMAT (1H0,3X,1HX,6X,1HY,6X,1HZ,10X,3HEXX,12X,3HETT,12X,
     1  3HEXT,9X,8HSIGMA XX,7X,8HSIGMA TT,7X,8HSIGMA XT,3X,6HREGION/
     2  2X,4H(IN),3X,4H(IN),3X,4H(IN),6X,7H(IN/IN),8X,7H(IN/IN),
     3  8X,7H(IN/IN),9X,5H(PSI),10X,5H(PSI),10X,5H(PSI))
 6000 FORMAT (51H0REACTIVE FORCES PER UNIT LENGTH ALONG EDGE (LB/IN)/
     1  6X,1HX,8X,1HY,9X,1HV,14X,1HN)
 6100 FORMAT (2F8.3,2E15.6)
 6200 FORMAT (33H0REACTIVE FORCES AT CORNERS (LBS))
      END
```

LIST2

```
*DECK PINIT
      SUBROUTINE PINIT(M)
*CALL CNOVA
*CALL CLOAD
*CALL CBLK1
*CALL CBLK8
*CALL CBLANK
      DIMENSION QQ1(3),QQ2(3)
      DATA QQ1/87.E-6, 90.E-6, 84.E-6/, QQ2/0.0686, 0.1127, 0.1275/
C
      IF(M.EQ.1) GO TO 200
      IF(KDS.EQ.2) GO TO 150
C
C     STATIC
C
      READ(5,2000) PS
      WRITE(6,2200) PS
      NU=1
      PPP=PS
  150 RETURN
C
C     DYNAMIC
C
  200 IF(KDS.EQ.1) GO TO 400
      READ (5,1000) NLOAD
      WRITE (6,2400) NLOAD
      GO TO (600,800,250,500), NLOAD
  250 READ(5,2000) PP1,PPO,TTO,TPRIME,AA,ANN
      WRITE(6,2300) PP1,PPO,TTO,TPRIME,AA,ANN
      NU=1
      IF(TPRIME.EQ.0.0) GO TO 300
      PPRIME=PPO*(1.0 - TPRIME/TTO)**ANN
      PPRIME = PPRIME*EXP(-AA*TPRIME/TTO)
      TT1=TPRIME*PP1/(PP1-PPRIME)
      OTT1=1.0/TT1
  300 OTTO=1.0/TTO
      AZ=AA*OTTO
  400 RETURN
C
  500 READ (5,1000) NTIME
```

```
      READ (5,2100) (TT(I),PT(I),I=1,NTIME)
      WRITE (6,2500) NTIME,(TT(I),PT(I),I=1,NTIME)
      NU = 1
      JL = 2
      RETURN
C     EGLIN SYMMETRIC, NONUNIFORM LOAD ON FLAT PLATE.
  600 VS = 5.00E4
      READ (5,2000) ZEE,PHI
      WRITE (6,2600) ZEE,PHI
      XO = XG(NG)
      YO = XB(NB)
      DO 700 I=1,NGT
      X = XG(I) - XO
      DO 700 J=1,NBT
      Y = XB(J) - YO
  700 RA(J,I) = SQRT(X**2 + Y**2 + ZEE**2)
      IPHI = 1
      IF (PHI.GT.0.0) IPHI = 2
      IF (PHI.GT.30.0) IPHI = 3
      Q1 = QQ1(IPHI)
      Q2 = QQ2(IPHI)
      NU = 0
      RETURN
C
  800 READ (5,1000) NPX,NPY,NTIME
      READ (5,2000) DTIM
      WRITE (6,2700) NPX,NPY,NTIME,DTIM
      READ (5,2000) (XP(I),I=1,NPX)
      WRITE (6,3100) (XP(I),I=1,NPX)
      READ (5,2000) (YP(J),J=1,NPY)
      WRITE (6,3200) (YP(J),J=1,NPY)
      WRITE (6,3300)
      DO 820 I=1,NPX
      READ (5,2000) (DET(J,I),J=1,NPY)
  820 WRITE (6,2800) (DET(J,I),J=1,NPY)
      WRITE (6,2900)
      DO 840 I=1,NPX
      DO 840 J=1,NPY
      READ (5,2000) (PRT(K,J,I),K=1,NTIME)
  840 WRITE (6,3000) (PRT(K,J,I),K=1,NTIME)
```

```
C     SPATIAL INTERPOLATION-EXTRAPOLATION.  INDICES ARE LOWER BOUND.
      DO 900 I=1,NGT
      DO 860 III = 1,NPX
      IF (XP(III).GT.XG(I)) GO TO 880
  860 CONTINUE
      III = NPX
  880 IF (III.GT.1) III = III - 1
      DX1(I) = (XG(I) - XP(III))/(XP(III+1) - XP(III))
  900 IXI(I) = III
      DO 960 J = 1,NBT
      DO 920 JJJ = 1,NPY
      IF (YP(JJJ).GT.XB(J)) GO TO 940
  920 CONTINUE
      JJJ = NPY
  940 IF (JJJ.GT.1) JJJ = JJJ - 1
      DY1(J) = (XB(J) - YP(JJJ))/(YP(JJJ+1) - YP(JJJ))
  960 JYJ(J) = JJJ
      NU = 0
      DO 980 I=1,NPX
      DO 980 J=1,NPY
  980 JLT(J,I) = 2
      RETURN
C
 1000 FORMAT (6I12)
 2000 FORMAT(6F12.1)
 2100 FORMAT (2F12.1)
 2200 FORMAT(24H0STATIC PRESSURE, PSI = E15.6)
 2300 FORMAT(23H0DYNAMIC LOAD CONSTANTS/
     1      11H  PP1    = E15.6/
     1      11H  PP0    = E15.6/
     1      11H  TT0    = E15.6/
     1      11H  TPRIME = E15.6/
     1      11H  AA     = E15.6/
     1      11H  ANN    = E15.6)
 2400 FORMAT (21H0DYNAMIC LOAD OPTION I4)
 2500 FORMAT (18H0NUMBER OF TIMES = I4/28H    TIME, SEC  PRESSURE, PSI/
     1  (2E15.6))
 2600 FORMAT (41H0DYNAMIC LOAD CONSTANTS - FLAT PLATE ONLY/
     1  14H  ZEE (IN)  = E15.6/ 14H  PHI (DEG) = E15.6)
 2700 FORMAT (23H0DYNAMIC LOAD CONSTANTS/
     1  12H    NPX     = I3/12H    NPY     = I3/
     2  12H    NTIME   = I3/12H    DTIM    = E15.6)
 2800 FORMAT (5X,5E15.6)
 2900 FORMAT (12H0PRESSURES =)
 3000 FORMAT (5X,6E15.6)
 3100 FORMAT (19H0X-POSITIONS (IN) =/(5X,5E15.6))
 3200 FORMAT (26H0Y-POSITIONS (IN OR DEG) =/(5X,5E15.6))
 3300 FORMAT (20H0DELAY TIMES (SEC) =)
      END
```

PINIT

```
*DECK PRESS
      SUBROUTINE PRESS
*CALL CNOVA
*CALL CLOAD
*CALL CBLK1
*CALL CBLK8
*CALL CBLANK
C
      IF(NCALL.GT.0) GO TO 1000
      ZZ= 1.0/RTRIAL(1)
      GO TO (400,800,50,220), NLOAD
   50 IF(TIME.GE.TPRIME) GO TO 100
      PPP=ZZ*PP1*(1.0 - TIME*OTT1)
      IF(PPP.LT.0.0) PPP=0.0
      GO TO 1000
  100 IF(TIME.GE.TTO) GO TO 200
      PPP=PPO*(1.0 - TIME*OTTO)**ANN
      PPP=ZZ*PPP*EXP(-AZ*TIME)
      GO TO 1000
  200 PPP=0.0
      GO TO 1000
C
  220 DO 240 J=JL,NTIME
      IF (TIME.LE.TT(J)) GO TO 260
  240 CONTINUE
      WRITE (6,250) TIME,TT(NTIME)
  250 FORMAT (32H ** WARNING - TIME EXCEEDS TABLE, 2E15.6)
      J = NTIME
  260 JL = J
      PPP = PT(J-1) + (TIME - TT(J-1))*(PT(J) - PT(J-1))/
     1  (TT(J) - TT(J-1))
      PPP = ZZ*PPP
      GO TO 1000
C
  400 DUM = TIME + ZEE/VS
      TD = Q1 - Q2*DUM
      PM = 484.95*DUM**(-.29)
      K = 0
      DO 600 I=1,NGT
      DO 600 J=1,NBT
      IF (NUSE(J,I).EQ.0) GO TO 600
      K = K + 1
      RRR = RA(J,I)
      TSTAR = (RRR - ZEE)/VS
      PPP = 0.0
      IF (TSTAR.GT.TIME + 1.0E-12) GO TO 500
      IF (TIME-TSTAR.GT.TD) GO TO 500
      FAC = (TSTAR - TIME)/TD
      CALPH = ZEE/RRR
      PPP = PM*CALPH*(1.0 + FAC)
  500 P(K) = PPP*ZZ
  600 CONTINUE
      GO TO 1000
C
C     INTERPOLATE ON TIME.
  800 DO 860 I=1,NPX
      DO 860 J=1,NPY
      PPP = 0.0
      DETT = DET(J,I)
      IF (TIME.LT.DETT) GO TO 860
      JL = JLT(J,I)
      DO 820 K=JL,NTIME
      KK = K
      IF (TIME.LE.DETT + DTIM*FLOAT(K-1)) GO TO 840
  820 CONTINUE
      JLT(J,I) = NTIME
      PPP = PRT(NTIME,J,I)
      GO TO 860
  840 JL = KK
      P1 = PRT(JL-1,J,I)
      T1 = DETT + DTIM*FLOAT(JL-2)
      PPP = P1 + (TIME - T1)*(PRT(JL,J,I) - P1)/DTIM
      JLT(J,I) = JL
  860 PRTT(J,I) = PPP
C     INTERPOLATE SPATIALLY.
      K = 0
      DO 880 I=1,NGT
      II = IXI(I)
      DX = DXI(I)
      DO 880 J=1,NBT
```

PRESS

```
      IF (NUSE(J,I).EQ.0) GO TO 880
      K = K + 1
      JJ = JYJ(J)
      DY = DY1(J)
      P1 = PRTT(JJ,II) + DY*(PRTT(JJ+1,II) - PRTT(JJ,II))
      P2 = PRTT(JJ,II+1) + DY*(PRTT(JJ+1,II+1) - PRTT(JJ,II+1))
      PPP = P1 + DX*(P2 - P1)
      P(K) = PPP*ZZ
  880 CONTINUE
C
 1000 RETURN
      END
```

PRESS

```
*DECK PROP
      SUBROUTINE PROP
C
*CALL FIRST
*CALL CBLK1
*CALL CBLK2
*CALL CBLK3
*CALL CBLK4
*CALL CBLK5
*CALL CBLK7
*CALL CBLK8
*CALL CBLK9
*CALL CBLK10
*CALL CBLK11
*CALL CBLK13
*CALL CBLK14
*CALL CNOVA
*CALL CBLANK
C
      IF(NCALL.EQ.0) GO TO 5700
      IF(NCALL.EQ.1) GO TO 5450
      PI=3.1415926535898
      ERRS=1.0E-5
      IFIRST=0
      JFIRST = 0
      NU = 1
C
      CALL DSET1
C
      CALL DSET2
      IF(KERR.GT.0) GO TO 6300
C
      CALL DSET3
C
      DO 5300 M=1,MG
      DO 5300 N=1,MB
      U1(N,M)=0.0
      V1(N,M)=0.0
      W1(N,M)=0.0
 5300 CONTINUE
```

```
      DO 5400 J=1,NY2
      XX(J)=0.0
 5400 ERR(J)=ERRB
      GO TO 5900
C
C
 5450 IF(KDS.EQ.2) GO TO 5900
      IF (PPP.EQ.0.0) GO TO 5900
C
C  STATIC SOLUTION
C
      NNELP = NELP
      NELP = 1
      KZ = 2
      NCOUNT = 0
      NOK=0
      NTR=0
      MTRMAX = 10
      CPTIM1 = SEC(DUM)
 5500 CALL DERV2
      CALL RELAXP(NY2,YY,XX,ERR,NOK,NDBUG,NCOUNT)
      ICOUNT = ICOUNT + 1
      NTR=NTR+1
      MTR=(NTR-2)/(NY2+1)
      IF (MTR.EQ.(NTR-3)/(NY2+1)) GO TO 5550
      IF (NDBUG.EQ.0) GO TO 5500
      IF (NDERV.EQ.1) CALL LIST1
      IF (NDERV.EQ.2) CALL LIST2
 5550 IF(MTR.GT.MTRMAX) GO TO 6200
      IF(NOK.EQ.0) GO TO 5500
      IF(NOK.GE.2) GO TO 6300
      MTR=(NTR-1)/(NY2+1)
      NELP = NNELP
      J=1
      DO 5600 M=1,MG
      DO 5600 N=1,MB
      IF(MUSE(N,M).EQ.0) GO TO 5600
      U1(N,M)=XX(J)
      V1(N,M)=XX(J+MGMB)
      W1(N,M)=XX(J+MGMB2)
      J=J+1
 5600 CONTINUE
      IF(KDS.EQ.3 .AND. NOBUG.EQ.0) GO TO 5900
      CPTIM3 = SEC(DUM)
      CPT=CPTIM3-CPTIM1
      WRITE(6,8350) MTR,CPT
      IF (NDERV.EQ.1) CALL LIST1
      IF (NDERV.EQ.2) CALL LIST2
      GO TO 5900
C
C   DYNAMIC RESPONSE
C
 5700 IFIRST=0
      CPTIM1 = SEC(DUM)
      J=1
      KC = 0
      DO 5750 M=1,MG
      DO 5750 N=1,MB
      IF(MUSE(N,M).EQ.0) GO TO 5750
      XX(J)=U1(N,M)
      XX(J+MGMB) = V1(N,M)
      XX(J+MGMB2)=W1(N,M)
      VXO(J)=0.
      VXO(J+MGMB)=0.
      VXO(J+MGMB2)=0.
      J=J+1
 5750 CONTINUE
      SMAX=0.0
      DPRT=-0.5*DELTIM
      TIME=0.0
      KHIM = 1
      TF = TSTOP + .5*DELTIM
 5760 CALL DERV2
      CALL HIM (KHIM,NY2,DELTIM,TIME,VXO,XX,YY)
      ICOUNT = ICOUNT + 1
      IF (KERR.GT.0) GO TO 6400
      IF (TIME.LT.TF) GO TO 5760
      WRITE (6,11400) TIME
      IF(KDAM.EQ.2) GO TO 5800
      CRIT(1)=SMAX
      WRITE(6,8400) NTRIAL,NCASE,RTRIAL(1),SMAX,TMAX
      IF(NELP .EQ.2) WRITE(6,8900) NREG
      IF(NTECO.EQ.1) WRITE(6,8500)
      IF(NTECO.EQ.2) WRITE(6,8600)
 5800 CPTIM3 = SEC(DUM)
      CPT = CPTIM3 - CPTIM1
      WRITE(6,9000) CPT
      IF(JFIRST.EQ.0) GO TO 5900
      NS=0
      DO 5850 L=1,LMAX
      IF(KY(L).GT.1) NS=NS+1
 5850 CONTINUE
      WRITE(6,9200) NS,LMAX
 5900 RETURN
C
C  ERROR MESSAGES
C
 6200 WRITE(6,8450) MTR
 6300 KERR = 1
      TIME = 0.
C
 6400 WRITE (6,11500) TIME
      RETURN
C
C  FORMAT STATEMENTS
C
 8350 FORMAT(26H1RESULTS OF STATIC PRELOAD/20H0NUMBER OF TRIALS = I5/
     115H NET CP TIME = F11.3)
 8400 FORMAT(17H0RESULTS OF TRIALI3,8H OF CASEI3/21H   RANGE, FT        =
     1 E15.8/21H   CRIT(1)          = E15.8/21H   TIME, SEC        = E15.8
     2)
 8450 FORMAT (35H0TOO MANY TRIALS IN STATIC SOLUTION/7H MTR = I4)
 8500 FORMAT(10H   TENSION)
 8600 FORMAT(14H   COMPRESSION)
 8900 FORMAT(25H   ELASTIC-PLASTIC REGIONI4)
 9000 FORMAT (33H0NET CP TIME FOR RESPONSE, SEC = F10.3)
 9200 FORMAT (1H0,I4,3H OF,I4,15H POINTS YIELDED)
11400 FORMAT(1H0//42H NORMAL DEPROP STOP CONDITION AT T, SEC = E14.6)
11500 FORMAT (1H //31H0DEPROP IS ABORTED AT T, SEC = E14.6)
      END
```

```
*DECK REIT
      SUBROUTINE REIT(I,J,K)
C     COMPUTE REACTIVE FORCES
*CALL CBLK1
*CALL CBLK3
*CALL CBLK7
*CALL CBLK10
*CALL CBLK11
*CALL CBLK14
*CALL CBLANK
      NBC = NBUSE(J,I)
      IF (NDERV.EQ.2) GO TO 600
C     NDERV = 1.
      IF (NBC.GT.100) GO TO 200
      IF (NBC.GT.0) GO TO 100
      NBC = -NBC
      VRX(NBC) = C1*WGGG(NBC) + C2*WBBB(NBC)
      ENX(NBC) = CM11*EXX + CM12*ETT
      IF (I.EQ.1) VRX(NBC) = -VRX(NBC)
      GO TO 1200
C
  100 VRT(NBC) = C3*WBBB(NBC) + C4*WGGB(NBC)
      ENT(NBC) = CM22*ETT + CM12*EXX
      IF (J.EQ.1) VRT(NBC) = -VRT(NBC)
      GO TO 1200
C
  200 NBC = NBC - 100
      RR(NBC) = C5*WBB(K)*(-1.0)**(NBC/2)
      GO TO 1200
C
C     NDERV = 2.
C
C     ELASTIC-PLASTIC.
C
  600 SUM = 0.0
      SUM1 = 0.
      JI = LBAR*(K-1)
      IF (NBC.GT.100) GO TO 1000
      IF (NBC.GT.0) GO TO 800
      NBC = -NBC
      JI1 = LBAR*(K-2)
      K2 = I*NBT + J
      IF (I.GT.1) K2 = (I-2)*NBT + J
      JI2 = LBAR*(K2 - 1)
      DELXX = DELX
      IF (I.EQ.1) DELXX = -DELX
      DO 700 KK = 1,LBAR
      L = JI + KK
      L1 = JI1 + KK
      L2 = JI2 + KK
      G1 = SXX(L)
      G11 = SXX(L2)
      G3 = SXT(L)
      G31 = SXT(L1)
      SUM = SUM + ((G11 - G1)/DELXX + 2.0*(G31 - G3)/DELT)*
     1  GX(KK)*HGO(KK)
  700 SUM1 = SUM1 + HGO(KK)*G1
      VRX(NBC) =  C5*SUM/2.0
      IF (I.EQ.1) VRX(NBC) = -VRX(NBC)
      ENX(NBC) = H*SUM1/2.
      GO TO 1200
C
  800 K1 = K - 2
      IF (J.EQ.1) K1 = K
      JI1 = LBAR*K1
      DELTT = DELT
      IF (J.EQ.1) DELTT = -DELT
      JI2 = LBAR*((I-2)*NBT + J-1)
      DO 900 KK = 1,LBAR
      L = JI + KK
      L1 = JI1 + KK
      L2 = JI2 + KK
      G2 = STT(L)
      G22 = STT(L1)
      G3 = SXT(L)
      G32 = SXT(L2)
      SUM = SUM + ((G22 - G2)/DELTT + 2.0*(G32 - G3)/DELX)*
     1  GX(KK)*HGO(KK)
  900 SUM1 = SUM1 + HGO(KK)*G2
      VRT(NBC) =  C5*SUM/2.0
```

REIT

```
      IF (J.EQ.1) VRT(NBC) = -VRT(NBC)
      ENT(NBC) = H*SUM1/2.0
      GO TO 1200
C
 1000 NBC = NBC - 100
      DO 1100 KK=1,LBAR
      L = JI + KK
 1100 SUM = SUM + GX(KK)*HGO(KK)*SXT(L)
      RR(NBC) = C5*SUM*(-1.0)**(NBC/2)
 1200 RETURN
      END
```

REIT

```
*DECK RELAXP
      SUBROUTINE RELAXP (NEQ,RES,X,ERR,NOK,NPRINT,NCOUNT)
      DIMENSION RES(1),X(1),ERR(1)
*CALL CBLK12
      DATA CON/5000./
      IF (NPRINT.NE.2) GO TO 40
      WRITE (6,50) (X(N),RES(N),N=1,NEQ)
   50 FORMAT (1H ,//4X,8H TRIAL X,10X,7HRESIDUE/(4X,E13.6,4X,E13.6))
   40 IF (NCOUNT.EQ.0 ) GO TO 10
      IF (NCOUNT.LE.NEQ) GO TO 14
      NCOUNT=0
      NQ=0
      NNQ=0
      DO  2  I=1,NEQ
      DX = X(I) - PX(I)
      IF (ABS(DX).LE.ERR(I)) NQ = NQ + 1
      IF (ABS(RES(I))-ABS(PRES(I)).GT.0.0)  NNQ=NNQ+1
    2 CONTINUE
      IF (NQ.EQ.NEQ) GO TO 100
      IF (NNQ.EQ.NEQ) GO TO 101
   10 DO 4  I=1,NEQ
      XX1(I)=X(I)
      RRES(I)=RES(I)
      DELX(I)=ABS(0.0001*X(I))
      IF (DELX(I).LT.ERR(I)) DELX(I)=ERR(I)
    4 CONTINUE
      GO TO 6
   14 DO 7  MM=1,NEQ
    7 XRES(MM,NCOUNT) = (RES(MM) - RRES(MM)) / DELX(NCOUNT)
      X(NCOUNT)=XX1(NCOUNT)
      IF (NCOUNT.EQ.NEQ) GO TO 8
    6 NCOUNT=NCOUNT+1
      X(NCOUNT)=X(NCOUNT)+DELX(NCOUNT)
      NOK=0
      RETURN
    8 DO 20  I=1,NEQ
   20 SIGX(I)=-RRES(I)
      CALL SOLVE (XRES,NEQ,147,0,IP,DET,SIGX)
      IF (NEQ.EQ.0) GO TO 15
      PROP=1.0
      DO 13 I=1,NEQ
      IF (ABS(SIGX(I)).LT.CON*ERR(I)) GO TO 13
      XPROP = CON*ERR(I)/ABS(SIGX(I))
      IF (XPROP.LT.PROP) PROP=XPROP
13    CONTINUE
      DO 12  I=1,NEQ
      X(I)=XX1(I)+SIGX(I)*PROP
      PX(I)=XX1(I)
   12 PRES(I)=RRES(I)
      NOK=0
      NCOUNT=NEQ+1
      RETURN
  100 NOK=1
      GO TO 11
  101 WRITE (6,55)
   55 FORMAT (32H0   SOLUTION DIVERGING IN RELAXP)
   15 NOK = 2
   11 NCOUNT=0
      RETURN
      END
```

```
*DECK SEC
      FUNCTION SEC (DUM)
C     FIND ELAPSED CP TIME.
C
      CALL SECOND (SEC)
      RETURN
      END
```

```
*DECK SIGMA
      SUBROUTINE SIGMA (I,J,M)
C
C     THIS S/R DETERMINES THE STRESS-STRAIN RELATIONSHIPS FOR
C       ELASTIC AND/OR PLASTIC RESPONSE.
C     SUBROUTINE COMPLETELY REVISED MARCH, 1976.
C
C     K - INDEX OF THE INTEGRATION POINT IN THE Z DIRECTION.
C     I - INDEX OF THE INTEGRATION POINT IN THE BETA DIRECTION.
C     J - INDEX OF THE INTEGRATION POINT IN THE GAMMA DIRECTION.
*CALL CBLK1
*CALL CBLK3
*CALL CBLK4
*CALL CBLK6
*CALL CBLK7
*CALL CNOVA
*CALL CBLANK
C
C
      DATA TOL/5.0E-3/
C
      IF(IFIRST.GT.0) GO TO 300
      IFIRST = 1
      EPO=SIGO/EL
      EPP = 0.0
      CN2 = 0.0
      SIGO2 = SIGO**2
      CN1 = (0.5 - TNU)/EL
      CN3 = 1.0/EL
      TNUSQ = TNU**2
      CN4 = (1.0 - TNUSQ)**2
      CN12 = (1.0 - TNU + TNUSQ)/CN4
      CN13 = (1.0 - 4.0*TNU + TNUSQ)/CN4
      CN4 = 0.75/((1.0 + TNU)**2)
      CN6 = EL/(1.0 - TNU**2)
      CN7 = EL*0.5/(1.0 + TNU)
      CN5 = 1.0/CN7
      LC = 0
      LCMAX = 100
      DO 100 L=1,LMAX
```

AD-A035 644   KAMAN AVIDYNE BURLINGTON MASS   F/G 1/3
DEPROP - A DIGITAL COMPUTER PROGRAM FOR PREDICTING DYNAMIC ELAS--ETC(U)
JUN 76   L J MENTE, W N LEE   F08635-76-C-0162
UNCLASSIFIED   KA-TR-133   AFATL-TR-76-71   NL

3 OF 3
ADA035644

END
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```
      IF (NELP.EQ.1) GO TO 70
      ALXX(L) = 0.0
      ALTT(L) = 0.0
      ALXT(L) = 0.0
      BE1(L) = 0.0
      BE2(L) = 0.0
      BE3(L) = 0.0
      TTNU(L) = TNU
   70 EPBO(L)=0.0
  100 KY(L) = 1
C
  300 KSUM = 0
C
      IJ = LBAR*(M-1)
      DO 3050 K=1,LBAR
      L = IJ + K
      H1 = ZF(K)
C     DETERMINE APPROPRIATE REGION.
      KEY  = KY(L)
      IF(KEY.GT.3) GO TO 350
      GO TO (400,600,700), KEY
  350 IF((KEY+1)/2.EQ.KEY/2) GO TO 600
      GO TO 700
C
C     REGION 1.  ELASTIC CURVE.
C
  400 KSUM = KSUM + 1
      IF(KSUM.GT.1) GO TO 450
      D1 = CN6*(EXX + TNU*ETT)
      D2 = CN6*(ETT + TNU*EXX)
      D3 = CN7*EXT
      D4 = CN6*(XKXX + TNU*XKTT)
      D5 = CN6*(XKTT + TNU*XKXX)
      D6 = CN7*XKXT
      S1A(M) = D1
      S2A(M) = D2
      S3A(M) = D3
      S4A(M) = D4
      S5A(M) = D5
      S6A(M) = D6
  450 G1 = D1 + H1*D4
      G2 = D2 + H1*D5
      G3 = D3 + H1*D6
      SIGBD =  G1*(G1 - G2) + G2**2 + 3.0*G3**2
      IF (NELP.EQ.2) GO TO 470
      EPBD(L)=SIGBD
      GO TO 3000
 470  IF(SIGBD.GE.SIGB2) GO TO 500
      EPBD(L)      = SIGBD
      GO TO 3000
  500 KY(L)       = KEY + 1
C     LINEARLY INTERPOLATE ON SIGMA BAR TO CORRECT FOR OVERSHOOT.
      SQSIG = SQRT(SIGBD)
      B2 = SQRT(EPBD(L))
      B1 = (SIGO - B2)/(SQSIG - B2)
      G1 = SXX(L)       + B1*(G1 - SXX(L))
      G2 = STT(L)       + B1*(G2 - STT(L))
      G3 = SXT(L)       + B1*(G3 - SXT(L))
      SIGXX1(L)       = G1
      SIGTT1(L)       = G2
      SIGXT1(L)       = G3
      T1   = CN3*(G1 - TNU*G2)
      T2   = CN3*(G2 - TNU*G1)
      T3   = CN5*G3
      EXX1(L) = T1
      ETT1(L) = T2
      EXT1(L) = T3
      EPBD = SQRT(CN12*(T1**2 + T2**2) - CN13*T1*T2 + CN4*T3**2)
      EPB(L)       = EPBD
      EPBD(L)       = EPBD
      IF (JFIRST.EQ.0) JFIRST = 1
      GO TO 3000
C
C     REGIONS 2 AND 4.  PLASTIC LOADING.
C
  600 EPBDP = EPB(L)
      H2 = EXX + H1*XKXX - BE1(L)
      H3 = ETT + H1*XKTT - BE2(L)
      H4 = EXT + H1*XKXT - BE3(L)
      CN2 = TTNU(L)
      II = 0
  610 II = II + 1
      CN22 = CN2**2
      EPBD = SQRT(((1.0 - CN2 + CN22)*(H2**2 + H3**2) -
     1  (1.0 - 4.0*CN2 + CN22)*H2*H3)/(1.0 - CN22)**2 +
     2  0.75*H4**2/(1.0 + CN2)**2)
      DELEP = EPBD - EPBD(L)
      EPP = (EP*DELEP + EL*EPBD(L))/EPBD
      IF (TNU.GT.0.0) CN2 = .5 - EPP*CN1
      IF (ABS(CN2-TTNU(L)).LT.0.0005) GO TO 620
      IF (II.GT.20) GO TO 615
      TTNU(L) = CN2
      GO TO 610
  615 WRITE (6,5500) CN2,TTNU(L),TIME
      GO TO 4100
  620 CN2 = TTNU(L)
      IF (EPBD.LE.EPBDP) GO TO 650
  630 EPB(L) = EPBD
      IF (EPP.GT.EL.OR.EPP.LT.EP) GO TO 4000
      S1 = EPP/(1.0 - CN2**2)
      S2 = 0.5*EPP/(1.0 + CN2)
      G1 = S1*(H2 + CN2*H3) + ALXX(L)
      G2 = S1*(H3 + CN2*H2) + ALTT(L)
      G3 = S2*H4 + ALXT(L)
      GO TO 3000
C
C     SECOND TEST FOR UNLOADING IN EITHER REGION 2 OR 4.
  650 D1=X1A(M)-EXX1(L) + H1*X4A(M)
      D2=X2A(M)-ETT1(L) + H1*X5A(M)
      D3=X3A(M)-EXT1(L) + H1*X6A(M)
      IF(EP.EQ.0.0)GO TO 660
      P1=SXX(L)-SIGXX1(L) + ALXX(L)
      P2=STT(L)-SIGTT1(L) + ALTT(L)
      P3=SXT(L)-SIGXT1(L) + ALKT(L)
      GO TO 670
  660 P1=0.0
      P2=0.0
      P3=0.0
  670 E1=D1 - H2
      E2=D2 - H3
      E3=G3 - H4
      G1=P1-CN6*(E1+TNU*E2)
      G2=P2-CN6*(E2+TNU*E1)
      G3=P3-CN7*E3
      A1=G1-P1
      A2=G2-P2
      A3=G3-P3
      SIGBD=A1*(A1-A2)+A2**2+3.0*A3**2
      IF (SIGBD.GE.SIGO2.AND.DELEP.GE.0.0) GO TO 630
C
      KY(L)=KEY+1
      TTNU(L)=TNU
      EPBO(L)=SIGBD
      BE1(L)=G1 + BE1(L)
      BE2(L)=G2 + BE2(L)
      BE3(L)=G3 + BE3(L)
      IF(EP.EQ.0.)GO TO 3000
      ALXX(L)=P1
      ALTT(L)=P2
      ALXT(L)=P3
      GO TO 3000
C
C     REGION 3.  ELASTIC UNLOADING - RELOADING.
C
  700 E1 = BE1(L) - EXX - H1*XKXX
      E2 = BE2(L) - ETT - H1*XKTT
      E3 = BE3(L) - EXT - H1*XKXT
      C1 = ALXX(L)
      C2 = ALTT(L)
      C3 = ALXT(L)
      G1 = C1 -                 CN6*(E1  + TNU*E2)
      G2 = C2 -                 CN6*(E2 + TNU*E1)
      G3 = C3 -                 CN7*E3
      A1 = G1 - C1
      A2 = G2 - C2
      A3 = G3 - C3
      SIGBD = A1*(A1 - A2) + A2**2 + 3.0*A3**2
      IF(SIGBD.GT.SIGO2)GO TO 800
      EPBO(L)=SIGBD
      GO TO 3000
```

```
C
C      LINEARLY INTERPOLATE ON SIGMA BAR TO CORRECT FOR OVERSHOOT.
  800 B2 = SQRT(EPBO(L))
      SQSIG = SQRT(SIGBO)
      IF(B2.GT.SIGO) GO TO 840
      NC = 0
  820 B1 = (SQSIG - SIGO)/(SQSIG - B2)
      NC = NC + 1
      IF(NC.GT.5) GO TO 830
      DEL1 = B1*(G1 - SXX(L))
      DEL2 = B1*(G2 - STT(L))
      DEL3 = B1*(G3 - SXT(L))
      G1 = G1 - DEL1
      G2 = G2 - DEL2
      G3 = G3 - DEL3
      A1 = G1 - ALXX(L)
      A2 = G2 - ALTT(L)
      A3 = G3 - ALXT(L)
      SQSIG = SQRT(A1*(A1-A2) + A2**2 + 3.0*A3**2)
      IF(ABS(SQSIG-SIGO)/SIGO.GT.TOL) GO TO 820
      GO TO 835
  830 WRITE(6,5700) NC,K,I,J,KEY,SQSIG,B1,B2,TIME
      LC = LC + 1
      IF (LC.GT.LCMAX) GO TO 4100
  835 CONTINUE
      DEL1 = G1 - SXX(L)
      DEL2 = G2 - STT(L)
      DEL3 = G3 - SXT(L)
      T1 = X1A(M) + CN3*(DEL1 - TNU*DEL2) + H1*X4A(M)
      T2 = X2A(M) + CN3*(DEL2 - TNU*DEL1) + H1*X5A(M)
      T3 = X3A(M) + CN5*DEL3 + H1*X6A(M)
      GO TO 880
  840 WRITE(6,5200) K,I,J,KEY,TIME,B2,SQSIG
      T1 = EXX + H1*XKXX
      T2 = ETT + H1*XKTT
      T3 = EXT + H1*XKXT
      LC = LC + 1
      IF (LC.GT.LCMAX) GO TO 4100
  880 EXX1(L) = T1
      ETT1(L) = T2
      EXT1(L) = T3
      M2 = T1 - DE1(L)
      M3 = T2 - DE2(L)
      M4 = T3 - DE3(L)
      EPBD = SQRT(CN12*(M2**2 + M3**2) - CN13*M2*M3 + CN4*M4**2)
      EPBO(L) = EPBD
      EPB(L) = EPBD
      SIGXX1(L)      = G1
      SIGTT1(L)      = G2
      SIGXT1(L)      = G3
      KY(L) = KEY + 1
      GO TO 3000
C
 3000 SXX(L)      = G1
      STT(L)      = G2
      SXT(L)      = G3
 3050 CONTINUE
      KSUMA(M) = KSUM
C
      RETURN
C
C     ERROR RETURN,
 4000 WRITE (6,5300) EPP,K,I,J,TIME,EPBD,EPBDP,EPBO(L)
 4100 WRITE (6,5400)
      KERR = 1
      RETURN
 5200 FORMAT (22H IMMEDIATE RELOADING  ,4I3,3E15.6)
 5300 FORMAT (28H0EPP IS OUT OF RANGE, EPP = E14.6/
    1  3I3,4E15.6)
 5400 FORMAT (21H0SOLUTION IS UNSTABLE)
 5500 FORMAT (26H VALUE OF NU WONT CONVERGE,2E15.6,15H   TIME, SEC =
    1  E15.6)
 5700 FORMAT (38H CAN NOT TOTALLY CORRECT FOR OVERSHOOT/5I5,4E15.6)
      END
```

SIGMA

```
*DECK SOLVE
      SUBROUTINE SOLVE (A,N,NDIM,NDET,IP,DET,B)
C
C     A     = ORIGINAL MATRIX.
C     N   = ACTUAL DIMENSIONS OF A.
C     NDIM = DECLARED DIMENSION OF A IN CALLING PROGRAM.
C     NDET = DETERMINENT CODE.
C            0 = NOT CALCULATED.
C              1 = CALCULATED.
C     IP    = INDEX OF K-TH PIVOT ROW.
C     DET   = DETERMINENT OF A.
C     B     = RIGHT HAND SIDE VECTOR.
C
      DIMENSION A(NDIM,NDIM),IP(NDIM),B(NDIM)
C
      IP(N)=1
      DO 6 K=1,N
      IF (K.EQ.N) GO TO 5
      KP1=K+1
      M=K
      DO 1 I=KP1,N
      IF (ABS(A(I,K)).GT.ABS(A(M,K))) M=I
    1 CONTINUE
      IP(K)=M
      IF (M.NE.K) IP(N)=-IP(N)
      T=A(M,K)
      A(M,K)=A(K,K)
      A(K,K)=T
      IF (T.EQ.0.0) GO TO 5
      DO 2 I=KP1,N
    2 A(I,K)=-A(I,K)/T
      DO 4 J=KP1,N
      T=A(M,J)
      A(M,J)=A(K,J)
      A(K,J)=T
      IF (T.EQ.0.0) GO TO 4
      DO 3 I=KP1,N
    3 A(I,J)=A(I,J)+A(I,K)*T
    4 CONTINUE
    5 IF (A(K,K).EQ.0.0) GO TO 15
    6 CONTINUE
      IF (NDET.EQ.0) GO TO 11
      DET=IP(N)
      DO 10 I=1,N
   10 DET=DET*A(I,I)
   11 IF (N.EQ.1) GO TO 14
      NM1=N-1
      DO 12 K=1,NM1
      KP1=K+1
      M=IP(K)
      T=B(M)
      B(M)=B(K)
      B(K)=T
      DO 12 I=KP1,N
   12 B(I)=B(I)+A(I,K)*T
      DO 13 KB=1,NM1
      KM1=N-KB
      K=KM1+1
      B(K)=B(K)/A(K,K)
      T=-B(K)
      DO 13 I=1,KM1
   13 B(I)=B(I)+A(I,K)*T
   14 B(1)=B(1)/A(1,1)
      GO TO 17
   15 WRITE(6,16)
   16 FORMAT (29H0SINGULAR MATRIX IN S/R SOLVE)
      N = 0
   17 RETURN
      END
```

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